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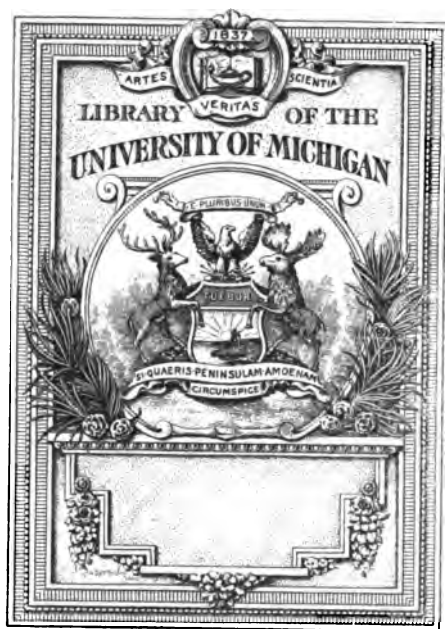
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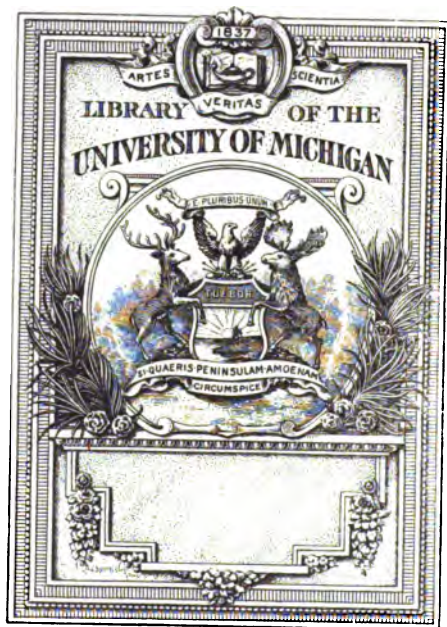
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PROCEEDINGS

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1892-1901

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ALPHEUS HYATT,

ROLAND THAXTER,

JAY B. WOODWORTH,

GLOVER M. ALLEN.

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No. 1. — *Proceedings of the Annual Meeting, May 3, 1899.*

REPORT OF THE CURATOR, ALPHEUS HYATT.

THE death of Mr. John Cummings of Woburn removes a member to whom this Society is indebted for valuable time freely given for many years in its Council and for much actual work done in its Museum, especially in the botanical department. While his pecuniary means were ample, he was as generous in giving aid with them as with his brain and hands. For a long time he carried on the botanical department, working in it himself and paying the salary of an assistant; he also maintained another assistant in the Museum, and at the same time supported the Teachers' school of science. His services in the botanical department were described in detail in my report for 1898 on the occasion of his retirement from that department which he had sustained from 1873 to 1898 and which he had succeeded in placing in excellent condition. Another monument to Mr. Cummings's generosity is the collection of European fossils filling Room H. This is the Eser collection, which is entirely his gift, and is one of the most famous of the older and smaller European collections. This collection is a great prize for any museum since it possesses very rare and valuable specimens and is especially suitable for the purposes of our educational series. The Teachers' school of science owes its foundation to Mr. Cummings and arose in the Council in consequence of his offer to support a series of lectures for teachers. The Curator immediately accepted this offer, and the school began in the following autumn. These are only his principal claims to our remembrance and gratitude, since it is impossible to take notice of the thousand and one services to the cause of science which he gave so generously and without expectation of credit or reward.

In his last annual report the Curator called attention to the necessity of doing something to perpetuate the office of Guide to the Museum. This has been held by Mr. Grabau and has become really a free lectureship, that has not only made our collections more instructive to the public but also interested a number of persons in the study of natural history and led to the giving of

many lessons on the sea-shore and in our laboratory or lecture room. This has greatly increased our usefulness to the community, and some means should be found to continue it.

An appeal was also made for aid in the botanical department. This is still cared for by Miss Carter but largely as a voluntary service, since only somewhat more than is sufficient to meet her expenses is now paid her.

Another part of the same report set forth the claims of the New England collection in our Museum, and the great need that exists of separating this from the educational and general systematic collections. The New England collections are scattered in the different departments and should be brought together in order to give a complete exposition of the natural products of our own neighborhood. The need of exhibiting in connected succession the mineralogy, geology, botany, and zoology of New England was fully demonstrated during the past summer when the American association for the advancement of science met in our building and in that of the Institute of technology and many of its members visited our Museum. If we had been able to throw open to them a series of collections showing such a connected history of the natural products of New England and of the geology of this region, it would have been a revelation of the teaching power of collections and might have had a far-reaching influence upon other museums in this country.

The Curator has always held that a New England museum should be brought together in this way within our building, and the whole be placed in order before any General guide could be effectively written. This year, however, the need for some guide to explain the apparent confusion to scientific visitors became urgent, and he wrote a small pamphlet of forty-seven pages, accompanied by a diagram of the building. This appeared as a second edition of a General guide written and published on the celebration of the fiftieth anniversary of this Society, but it is in reality new.

TEACHING IN THE MUSEUM.

The operations of this department have ceased for want of funds, as has been noted above.

DYNAMICAL ZOOLOGY.

Considerable work on this collection has been done. The different series have been rearranged and general descriptive labels prepared by the Curator assisted by Miss Bryant. The large relief map of Oahu shows with the aid of colored pins the migrations of the species of three of the principal genera of Achatinellidae. The genera are represented by pins with heads of different colors, and the species are represented by different numbers and labels on the pins. In this way the migrations of the species may be followed along the mountain ridges of the island, and the correlation of these movements with topography is brought out more clearly than by the use of the shells themselves. A valuable and interesting series of lamprey eels has been given to this collection by Prof. S. H. Gage of Cornell.

MINERALOGY AND GEOLOGY.

During the summer Professor Crosby gave considerable time to the geological department of the Museum, putting the specimens on exhibition in more perfect order, labeling new specimens, etc., and he also labeled and arranged, as well as the limited space now available would permit, the illustrative specimens and maps prepared for Parts 1 and 2 of the Boston Basin work, and for Part 3 so far as that was then completed. The same assistant has also completed a much needed revision of the general collection of minerals and incorporated with the mounted specimens on exhibition all of the materials that have been accumulating in the past ten years. Professor Crosby has also personally paid for the necessary clerical assistance employed in this work.

During the meeting of the American association for the advancement of science he presented before Section E an outline of the history of the Blue Hills complex, and abstracts of this paper appeared in the American geologist, in Science, and in the Proceedings of the American association. He also conducted seven parties of geologists to points of local interest, including the Blue Hills, and had the satisfaction of learning that his views concerning the geology of this exceedingly difficult region were endorsed by competent authorities.

Another gratifying result of going over the ground with these geologists was the offer of further cooperation. Professor Crosby's work is necessarily mainly areal and structural, and although he has himself paid for a number of chemical analyses and has received additional assistance from several of his students, it was very desirable that this should be supplemented, especially for the igneous rocks, by microscopic and chemical work. Dr. White of Columbia has very kindly done considerable microscopical work on the Blue Hills rocks, and Dr. A. S. Eakle of Harvard has kindly supplemented this by investigations of the plutonic rocks, especially on chemical lines. The intricate nature of the problem of the geology of this region has been the cause of the successive delays in completing the work, and it would still have remained unfinished if Professor Crosby had not this year given an extraordinary amount of time to this purpose.

The manuscript of Part 3, "The Blue Hills complex," is now in the hands of the Secretary, 375 pages, with 8 plates and 26 figures. Two chapters which Mr. Grabau is writing, one on the fossils and one on Lake Bouvé, an extinct glacial lake, noticed in the report for 1895-96, are in the hands of the author, but are stated to be practically finished. An important accession of new fossils lately received, including the Sears collections from Nahant and Mr. W. W. Dodge's collections from Braintree, has prevented the completion of the descriptions of the fossils in time for this report, but it is gratifying to notice that these accessions have about tripled the materials for investigation.

The work on the Neponset Valley, Part 4, of the Boston Basin work, has been actively pressed. Outside the areal and structural work done by Professor Crosby, Dr. Florence Bascom, of Bryn Mawr college, accepted an invitation to contribute by studying the volcanic rocks, and Mr. F. C. Ohm of the U. S. geological survey has also kindly taken the work on the thin sections, while Professor Crosby has arranged for a sufficient number of chemical analyses to supplement Miss Bascom's investigations.

Professor Crosby ends his report to the Curator as follows: "The willingness of other geologists to cooperate with me is a great encouragement and leads me to hope that the ideal end of this work may be realized; viz: an illustrated handbook of the local geology of our own neighborhood accompanied by a complete collection on exhibition in suitable rooms. This should not only be creditable to

the Society and of great educational value, but also stand the test of close and critical comparison with facts in the field."

That this hope is not too highly aimed is shown by the fact, that it is even now in large part realized. This can be demonstrated by the accumulated collections and maps, by the willingness of able observers to cooperate in the laboratory and in the field, and also by a published opinion emanating from the highest authority. The Hon. C. D. Walcott, Director of the U. S. geological survey and the leading investigator of Cambrian rocks, wrote in 1871 of Professor Crosby's work in his *Correlation of the Cambrian*, Bull. U. S. geol. surv., no. 81, p. 268, as follows: "The description of the Cambrian rocks of the Boston Basin by Professor W. O. Crosby is the most recent and the most thorough of any we have, and the summary of our present knowledge of them is taken mainly from his paper."

SYNOPTIC ZOOLOGY.

Mrs. J. M. Arms Sheldon has contributed by the purchase of suitable specimens for this department, having drawings framed, etc., at her own expense, as well as by the donation of far more personal work than the time called for by the duties of her position as assistant in the Museum.

She spent considerable time in the spring and summer in making the whole collection more presentable and in placing on exhibition most of the fine specimens and drawings that have been slowly accumulating during several years past, so that the larger part of the Invertebrata now present a far better aspect than at the beginning of the present official year. About 314 specimens and 61 plates containing 266 figures were added to the collection, 172 of which were mounted by Mrs. Sheldon.

The worms have been completed, 67 drawings having been selected and arranged in plates, 12 tablets of mounted specimens added to this section of the collection, and about 95 pages of manuscript written. Considerable work has also been done upon the Brachiopoda and Pelecypoda, and upon the arrangement of Tunicata. Eighty specimens mostly Brachiopoda have been mounted and placed on exhibition; also eight genera of Tunicata and two of Cephalopoda. Considerable additions have also been made to the text of the Guide in the Actinozoa and Brachiopoda and some-

thing on Pelecypoda. A considerable number of fossil Gasteropoda have also been selected from the general collections, mounted, and placed on exhibition. Mrs. Sheldon has also described about fifty-eight species of Crustacea and selected and mounted a limited number of specimens.

Miss Martin has been as usual more or less occupied in making colored drawings for this collection, especially during the summer. The labeling of the tablets has been done by Miss Bryant and also the preparation of some of the fossils.

BOTANY.

Less work than in previous years has been done upon the herbarium, owing in part to the unfortunate sickness of the assistant, Miss Carter. She nevertheless continued through a large part of the past official year the work upon the labeling of the Lowell collection and systematic arrangement of the duplicates and the poisoning of the plants. During the summer she also looked over and cleaned the specimens on exhibition and placed in position a series of shelf labels indicating the different divisions of plants, and Miss Bryant assisted her by making these labels. Thirty species of North American lichens were added by purchase from Cummings, Seymour, and Earle. Nineteen persons have been permitted to consult and study in the herbarium.

PALAEONTOLOGY.

Miss Bryant has this year worked upon the renovation of the tablets and specimens in the European room, especially in Oolite, and has rewritten about four hundred labels. She has also worked over all of the American Jurassic and Cretaceous fossils and has cleaned from the matrix and mounted a number of Silurian fossils of the American collection from Anticosti, and a collection of fossils from the St. John's group has also been cleaned and mounted by the same assistant. A number of Devonian corals purchased from Mr. Greene have been identified and labeled, and the Vertebrata from the Cretaceous freshly labeled. The same assistant revised the work previously done by other assistants upon the Trenton and Niagara fossils and relabeled them. She also finished the Carboniferous fossils including the Brachiopoda, Lamellibranchiata, Gasteropoda, and Cephalopoda.

MOLLUSCA.

The large collection purchased of Rev. J. T. Gulick last year and described in the report of 1898 has been completely catalogued and every lot labeled, each shell having been also numbered. The collections of Achatinellidae previously mentioned have been still further increased by the loan of eight thousand shells belonging to Mr. C. M. Cooke, Jr., of Honolulu, making in all about thirty thousand shells of this family at present available for study. The Curator has found it essential to trace as far as practicable the migrations of the Achatinellae from island to island, and has made good progress during the past year, having reviewed most of the genera that are found in islands outside of Oahu. A small but valuable collection of Achatinellidae from the island of Molokai that filled a number of blanks in our own collection has been given us by Dr. W. P. Wesselhoeft. Miss Martin completed the work of labeling the duplicate Gasteropoda having no locality labels, and these were in part given away to the public schools and in part exchanged for invertebrates collected in the West Indies by Mr. C. J. Maynard. Miss Martin has made a complete series of colored drawings of the animals of Pteropoda and arranged these in company with a series of the shells purchased from Mr. Sowerby.

The death of Mr. Edward W. Roper, a member who had taken a great interest in this collection and was practically an assistant in this department, was a severe loss. He had, in the short time that he was connected with us before his health obliged him to seek refuge in southern California, done much efficient work, and had also planned the revision of all our land shells. His entire conchological collection was bequeathed to us and is now in our possession, with the exception of the Cyrenidae. These are in the hands of Mrs. Roper, who will deliver them to us as soon as practicable after her return to the east. A detailed report on this collection will be made after these have been received and the whole collection has been catalogued. This work has been begun by Miss Martin.

CRUSTACEA.

The work of restoring the faded labels of alcoholic preparations, begun by Miss Martin last year, was renewed this year, and will be

continued during the coming year. Professor Kingsley of Tufts college, to whom our collection of Amphipoda was loaned for investigation, reports that about one fourth of the specimens have been named and that the whole collection is in good condition.

BIRDS AND MAMMALS.

The New England collection of birds was removed from the cases during the early part of this official year and the new backs put into the cases with its new shelving brings the specimens close to the glass where they can be readily seen and examined. The specimens were removed and returned to their places by Miss Martin, and the arrangement was subsequently revised by Mr. Batchelder.

The Mammalia were also removed and the cases in the main gallery immediately adjoining the entrance to Room N were deepened. This enabled Miss Martin to place the collection of New England mammals outside of Room N and thus make sufficient space for the extension of the collection of birds within that room. The arrangement of the mammals also was revised by Mr. Batchelder.

A railing case of improved pattern was built early in the summer along the east side of the upper gallery for the accommodation of the larger specimens of birds' nests and eggs promised by the Nuttall ornithological club. Mr. Batchelder removed from their cases all of the old collection of birds' nests and eggs, which had for some years been in bad condition, and cleaned and rearranged them, weeding out undesirable material during the process. A part of the donation of the Nuttall club has been received and placed in the cases by Mr. Batchelder. This makes a fine appearance, and the sincere thanks of the Society are due to the members of the Club for a donation which has so greatly improved this part of our New England collections, and to Mr. Batchelder for the expense and trouble incurred in appropriately mounting these handsome specimens. Unfortunately Mr. Batchelder met with a serious accident a few weeks since, and this has stopped for the present the active work he was doing in the collections under his charge, but, as this report shows, his efforts this year had already laid the Society under obligations which should be gratefully acknowledged.

During the summer the Curator succeeded in obtaining a rare species of whale, *Mesoplodon bidens*, noticed at the meeting of November 2, 1898. The bones of this specimen are now being prepared for the collection.

LABORATORY.

The room in our basement has been this year used as in previous years by the classes of the Boston university and Teachers' school of science. A number of new diagrams have been made for use in the laboratory and the specimens have been looked after by the Curator and Miss Martin.

REMARKS.

A much larger amount of work upon the collections not reported upon above has been done this year than usual, especial efforts having been made to bring into order and work up our miscellaneous alcoholic and dry materials. It should also be noted here that these annual reports take no notice whatever of this sort of work nor of similar work upon the various collections, such as the general inspection and repair of dried specimens, the poisoning of the same twice in each year, the inspection of alcoholic specimens and the refilling of bottles once in each year, the reception and preparation of specimens, and other items of daily routine.

The Museum has been visited during private days by 340 pupils and teachers, representing 12 schools, all of whom have as heretofore been admitted without charge. It should also be noted here that this year as in previous years several artists have been allowed to draught specimens or study them in the Museum on closed days free of charge.

TEACHERS' SCHOOL OF SCIENCE.

Mr. Grabau has continued his excursions and lectures upon zoology. The Saturday field courses have been regularly carried on. Four excursions were made in May and June, 1898, in addition to those reported upon in the last annual report. These took in the more important localities on our coast and the fresh-water ponds of West Cambridge. A three days' excursion to Wood's Holl was

also made and notwithstanding the length of time consumed and the expense of such a prolonged trip, this was taken by ten persons. The days were spent in the general study of the fauna of the shores and the evenings in surface work. Reports and theses on the specimens found and preserved were subsequently prepared, each student selecting a distinct group of animals. Another longer excursion of ten days was made to Gouldsborough on Frenchman's Bay, Maine. Several boats together with dredging apparatus were placed at the command of this party. The habits of marine animals were the principal subject for observation on this trip. As on previous trips an effort was made to collect extensively, and lists of the species are in preparation as part of the theses of the members of the class. Several members of this class made an independent excursion of several weeks' duration to the island of Monhegan and collected a large number of marine invertebrates, some of which have not been heretofore reported from this part of the coast. The autumn course of field lessons in zoology also given by Mr. Grabau began September 10, and ten lessons were given; but owing to the exceptional inclemency of the weather, eight of these were necessarily transformed into laboratory exercises. The average attendance was twenty.

The Hale house natural history club, founded by members of these classes, still continues to work in cooperation. All remuneration ceased with the close of the spring courses, and since then Mr. Grabau has been conducting the instruction without pay, excepting in so far as the members of the classes have defrayed his traveling expenses and the cost of circulars and correspondence. Unless some substantial support can be obtained for this work, it must cease, and the fruit of years of preparation as well as several years of direct work will be lost. A few hundred dollars per year would enable us to carry on these classes which must eventually exercise a large influence upon our efforts to investigate and excite a general interest in the natural history of New England.

Our work upon the geology of this region is in full swing with two able men, one constantly investigating and publishing, the other at the head of a large, enthusiastic, and increasing class of teachers in the public and private schools.

The zoology has also been successful and will do quite as much for the biological side of our work, if it meet with equal patronage.

The spring work in zoology has been begun with one regular

excursion to Nahant and a number of informal trips, and will be continued for the present.

Professor Barton had arranged to give ten field lessons in geology to the pupils of the Boston normal school but the exceptionally bad weather in the autumn of 1898 reduced these to four. This class consisted of twenty young ladies and was conducted without remuneration. The indifference of the authorities to the continuance of this course, in spite of the exertions of the teacher in charge and of the head of the school to obtain an appropriation for this purpose, exhibits quite plainly the estimate in which science is held by the government of the public schools. Professor Barton states that these pupils, all of whom are to be teachers in the public schools, come to him exceedingly well prepared for the work by their previous training and are very enthusiastic and successful, but as he has now been carrying these courses for several years without remuneration he will be unable to continue after the series of lessons now being given is finished. The spring course has begun and will be reported upon next year.

The field lessons in geology in the autumn of 1898, although no longer supported by the Lowell fund, were conducted voluntarily by Professor Barton in order that the teachers who had counted upon having them should not be disappointed and in the hope that means would be found to keep this important part of the work of the school from being given up altogether. Luckily our appeals for help were in this case answered by a generous friend of the Society, who has promised a sum sufficient to carry on these courses through the spring and autumn of 1899.

The autumn course began September 17, 1898, and ended November 19, ten lessons having been given. The whole number of applications was 110 and the average attendance notwithstanding the bad weather was twenty-seven. There was but one fair day out of the ten Saturdays upon which lessons were held. Most of these lessons occupy one half day but some, like those to Marblehead, Rockport, Haverhill, Fitchburg, require a whole day and those to Hoosac Tunnel and Mt. Holyoke took three days each. The spring course of 1899 has begun and will be noticed fully in the next annual report.

A party of seventeen under Professor Barton's direction visited Nova Scotia during the summer of 1898, spending about three weeks in making a study of the geology, mineralogy, mining, and

natural scenery of that country. Among the prominent points visited were the coal mines at the Joggins, the iron mines at Londonderry, the gold mines at Montagu, the gypsum quarries at Windsor, the famous mineral localities at Partridge Island, Wason's Bluff, and Cape Blomidon, and the beautiful scenery around Halifax and the Annapolis Valley. Many courtesies were shown the party by the managers of the different mines and by others. The members of the class were charged with the teacher's expenses and a fee of five dollars each. A similar excursion into western Massachusetts and westwards as far as Niagara Falls has been planned for the coming summer.

LOWELL FREE COURSES.

The regular spring course of ten field lessons in geology carried on by Professor Barton began April 23, 1898, and ended June 25. Bad weather interfered with the work and reduced the attendance to less than it ever has been before. While in 1897 for the same course it was 34, this spring the average was only 10.

The Curator regrets to announce that the Trustee of the Lowell institute having decided to discontinue the out-of-door work of the Lowell free course in the Teachers' school of science, will contribute in future only to the support of lectures during the winter. To this determination he has been led by considerations of general policy which in no way reflect upon the value or success of the field courses.

It would be difficult to overstate the obligations of this Society to Mr. Augustus Lowell. This gentleman as Trustee of the Lowell institute has carried on for many years past most of the lessons given by the Teachers' school of science and preceding this time gave freely towards the maintenance of courses of free public evening lectures. He assumed the support of the field lessons in geology in 1890, and they have since then been a part of the work of the Lowell institute and have thus been able to build up results that ought to secure for them some permanent foundation.

A new four years' course (120 hours) in geology under Professor Barton began during the past winter. This course like that which preceded it will embrace at least fifteen lessons of two hours each, thirty hours for each year of the course. The subjects are to

be as follows: mineralogy, lithology and dynamic geology, structural geology, and historical geology.

The first year's course on mineralogy began on December 5, 1898, and ended on April 15, 1899. This included one extra lecture which was given by special request at the end of the regular lessons and the final examination, making seventeen exercises, in all thirty-four hours of instruction instead of the required thirty hours. The entire number of applications received for this course was 145, and special provision was made to accommodate 130 of these. The unusual prevalence of sickness during the winter caused the loss of several from the class and a few also withdrew as they found the work more difficult than they could attend to in connection with the necessary work in their schools. The average attendance for the course was 106. Of these 72 took all the examinations, including the final. The instruction included one introductory lecture upon chemistry, four upon crystallography, and ten upon mineralogy proper. They were given by means of lectures, supplemented by a complete series of minerals illustrating the commoner species, about 130 in number. Each two members of the class had one tray between them, containing all the species discussed at any single lesson, and this enabled each member of the class to study with the specimens directly in hand. A complete set of notes was also supplied each member of the class, for which a cost price was charged. At each lesson except the first and the last the first half hour was devoted to an examination covering all the ground previously passed over, and at the end of the course a final examination of three hours was given which was so arranged as to present a concise résumé of the whole subject.

Dr. R. W. Greenleaf gave a course of fifteen lessons of two hours each upon the principles of the classification of flowering plants. One hundred species of native plants were collected, dried, mounted, and divided into sets by Miss E. B. Bryant, and each student was provided with one of these. Fresh material was also purchased when required for the use of the class. The class was especially indebted to Miss Helen Sharp, formerly an assistant in this course, for the use of her collection of water-color drawings of 901 sheets, 774 of which represent American plants, the actual number of American species being 649. These drawings will shortly be assembled and exhibited in our laboratory, where they can be seen as a whole and properly inspected. This free public exhibition will

take place between the 9th and 13th of May, and will be open daily from 12 to 4.30. There were forty persons in the class and the average attendance was twenty-seven. Twenty-one persons took the examination, out of which number nine passed with honor, seven with credit, four simply passed, and one failed.

The Curator gave the fourth year of a five years' course in zoology, consisting this year of sixteen lessons of two hours each. The subjects were Myriopoda, Arachnozoa, and Insecta through Coleoptera, leaving the Lepidoptera and other so-called higher orders to be treated next year. The number of tickets issued was forty-five and the average attendance twenty-five. The excessively bad weather had a depressing effect upon this course as upon most others. Thirteen only took the final examination and all of these passed.

REPORT OF THE SECRETARY AND LIBRARIAN, SAMUEL HENSHAW.

MEMBERSHIP.

During the past year eighty-four Corporate members have been elected by the Council. Nine Corporate members have become Life members. One Honorary member, James Hall, has died. Three Corresponding members, George Baur, Oliver Marcy, and O. C. Marsh, have died.

From the list of Corporate members we have lost by death five names, John Cummings, Edmond E. Fernald, James I. Peck, Henry P. Quincy, and Edward W. Roper.

Two Corporate members have resigned, and the names of fourteen have been stricken from the list for non-payment of dues.

The membership of the Society, corrected to May 3, 1899, consists of 10 Honorary, 139 Corresponding, and 420 Corporate members, a total of 569. There are 17 Patrons.

The number of Corporate members reported last year was 363; twenty-three is the greatest number elected in any of the antecedent seven years, and for the essential increase this year the Society is indebted mainly to the abundant faith and efficient work of its President, Professor Minot.

The names of the Corporate members elected and the dates of their election are as follows:—

Arthur Amory, Feb. 15, 1899.
 S. Reed Anthony, Feb. 15, 1899.
 Francis Blake, Feb. 15, 1899.
 Mrs. T. M. Brewer, Feb. 15, 1899.
 Shepherd Brooks, Feb. 15, 1899.
 Edward I. Browne, Feb. 15, 1899.
 Arthur T. Cabot, Mar. 29, 1899.
 William B. Cabot, Apr. 26, 1899.
 Alvin Carl, Mar. 29, 1899.
 Mrs. J. B. Case, Mar. 29, 1899.
 John S. Clark, Mar. 29, 1899.
 Collier Cobb, Feb. 15, 1899.
 Miss Helen Collamore, Feb. 15, 1899.
 T. Jefferson Coolidge, Jr., Feb. 15, 1899.
 Charles U. Cotting, Feb. 15, 1899.
 Miss S. H. Crocker, Feb. 15, 1899.
 Miss Ada Dana, Oct. 19, 1898.
 Andrew McF. Davis, Feb. 15, 1899.
 James C. Davis, Mar. 29, 1899.
 Gordon Dexter, Feb. 15, 1899.
 Thomas Doliber, Mar. 29, 1899.
 Richard S. Dow, Feb. 15, 1899.
 Raymond B. Earle, Feb. 15, 1899.
 G. B. Eisenhard, Oct. 19, 1898.
 Mrs. J. W. Elliot, Mar. 29, 1899.
 George W. Fitz, Feb. 15, 1899.
 Charles F. Folsom, Feb. 15, 1899.
 Eugene N. Foss, Mar. 29, 1899.
 Charles Fry, Mar. 29, 1899.
 George M. Garland, Feb. 15, 1899.
 George W. Gay, Feb. 15, 1899.
 Harold B. Goodrich, Mar. 29, 1899.
 Mrs. Mary T. Gorham, Feb. 15, 1899.
 Francis C. Gray, Feb. 15, 1899.
 Mrs. Caroline W. Greenough, Mar. 29, 1899.
 Charles P. Greenough, Feb. 15, 1899.
 Elisha H. Gregory, Jr., Oct. 19, 1898.
 Miss Minna B. Hall, Mar. 29, 1899.

Francis R. Hart, Feb. 15, 1899.
Charles E. Hellier, Feb. 15, 1899.
Mrs. Augustus Hemenway, Feb. 15, 1899.
Joseph P. B. Henshaw, Feb. 15, 1899.
Hibbert W. Hill, Mar. 29, 1899.
Robert C. Hooper, Feb. 15, 1899.
Theodore Hough, Mar. 29, 1899.
John E. Hudson, Feb. 15, 1899.
Willard P. Hunnewell, Mar. 29, 1899.
Charles E. Inches, Feb. 15, 1899.
Charles F. Jenney, Oct. 19, 1898.
Miss Marian H. Judd, Feb. 15, 1899.
William Lawrence, Feb. 15, 1899.
George W. Lee, Dec. 21, 1898.
William C. Loring, Feb. 15, 1899.
Charles Lowell, Apr. 26, 1899.
Charles P. Lyman, Apr. 26, 1899.
Vernon F. Marsters, Mar. 29, 1899.
Asa E. Mattice, Mar. 29, 1899.
Laurence Minot, Feb. 15, 1899.
William Minot, Feb. 15, 1899.
William J. Moenkhaus, Dec. 21, 1898.
Miss Margaret W. Morley, Feb. 15, 1899.
Elisha W. Morse, Dec. 21, 1898.
Mrs. Edith J. Nichols, Mar. 29, 1899.
Edgar W. Olive, Oct. 19, 1898.
Edward C. Perkins, Feb. 15, 1899.
John C. Phillips, Oct. 19, 1898.
Dudley L. Pickman, Feb. 15, 1899.
David Pingree, Feb. 15, 1899.
William H. Ruddick, Dec. 21, 1898.
Mrs. T. E. Ruggles, Oct. 19, 1898.
Dudley A. Sargent, Mar. 29, 1899.
Alfred L. T. Schaper, Feb. 15, 1899.
Frederic F. Smith, Feb. 15, 1899.
John E. Thayer, Feb. 15, 1899.
Augustus L. Thorndike, Mar. 29, 1899.
Miss Mary M. Webster, Feb. 15, 1899.
Clarence M. Weed, Oct. 19, 1898.
William P. Wesselhoeft, Feb. 15, 1899.

Henry M. Whitney, Feb. 15, 1899.
 George Wigglesworth, Feb. 15, 1899.
 Guy M. Winslow, Feb. 15, 1899.
 Edward S. Wood, Mar. 29, 1899.
 Miss Elvira Wood, Dec. 21, 1898.
 Frederick A. Woods, Dec. 21, 1898.

MEETINGS.

Fourteen regular meetings including the Annual meeting have been held during the year; one Special meeting has been held. The attendance shows an average of 55 *plus*, the largest at any one meeting being 144, the smallest 24; the largest last year was 352, the smallest 24.

Twenty-six communications have been made by twenty-two persons; of the twenty-two persons seven have not previously spoken at our meetings.

Twelve papers have been presented by title.

The substitution of electricity for gas in the lecture room and the availableness of the lantern for even a modicum of illustration are features that should add to the success of future meetings.

The Society and especially the Secretary are indebted to Dr. R. T. Jackson for his kindness in serving as recorder at meetings in January and February.

The meetings, attendance, and communications have been as follows:—

May 4, 1898. Annual meeting. Forty-two persons present.

Reports of the Curator, Secretary, Librarian, Treasurer, and Trustees.

Mr. J. Edmund Woodman. Geological history of the gold-bearing slates of Nova Scotia.

Mr. M. L. Fernald. The genus *Antennaria* in New England. (By title.)

Prof. C. S. Minot. On the veins of the Wolffian bodies in the pig. (By title.)

Dr. P. P. Calvert. The odonate genus *Macrothemis* and its allies. (By title.)

Mr. T. D. A. Cockerell. The North American bees of the genus *Prosapis*. (By title.)

May 18, 1898. General meeting. Thirty-two persons present.

Dr. T. A. Jagger, Jr. The Absaroka range of the Rocky Mountains.

November 2, 1898. General meeting. Thirty-seven persons present.

Prof. Alpheus Hyatt. A rare whale from the Massachusetts coast.

Dr. R. T. Jackson. Localized stages in growth in plants and animals.

Dr. G. N. Calkins. Some hydroids from Puget Sound. (By title.)

Mr. Reginald Heber Howe, Jr. North American wood frogs. (By title.)

November 16, 1898. General meeting. Eighty-five persons present.

Prof. W. Z. Ripley. Racial characteristics of the Jews—a study in physical anthropology.

December 7, 1898. General meeting. Forty-five persons present.

Dr. G. H. Parker. On the coronary circulation in some fishes.

Prof. M. A. Willcox. On the occipital region of the head in the European trout.

Prof. J. S. Kingsley. Ear-bones of mammals.

Prof. C. S. Minot. Prof. O. van der Stricht's demonstration of the human ovum.

Prof. C. S. Minot. Some classical embryological monographs.

December 21, 1898. General meeting. Forty-three persons present.

Prof. Alpheus Hyatt. Evolution and migrations of the land shells of the Hawaiian Islands.

January 4, 1899. General meeting. Thirty-six persons present.

Mr. J. B. Woodworth. The geology and geography of the Richmond area in Virginia.

January 18, 1899. General meeting. Forty-four persons present.

Dr. Frank Russell. An account of the Apache festival of San Antonio.

February 1, 1899. General meeting. Seventy-six persons present.

Dr. R. A. Daly. A geological tour in Russia, Finland, the Volga, the Caucasus, and the Crimea.

February 15, 1899. General meeting. Thirty-two persons present.

Mr. Myron L. Fuller. Rapidity of sand-plain growth.

Prof. W. O. Crosby. Geology of the main dam and tunnel of the Metropolitan water works, near Clinton, Mass.

- February* 17, 1899. Special meeting. Eighty-six persons present.
 Prof. H. F. Osborn. Evolution of the Mammalia in North America.
- March* 1, 1899. General meeting. Thirty-four persons present.
 Dr. T. A. Jaggar, Jr. The intrusive rocks of the Black Hills.
- March* 15, 1899. General meeting. Twenty-eight persons present.
 Mr. E. C. Jeffrey. Development and affinities of the genus *Equisetum*.
 Dr. C. R. Eastman. Some new North American fossil fishes.
- April* 5, 1899. General meeting. Sixty-three persons present.
 Report of the Nominating committee.
 Prof. C. E. Fay. The Alpine features of the Canadian Rockies.
- April* 26, 1899. General meeting. One hundred and forty-four persons present.
 Dr. W. McM. Woodworth. Samoa and the Samoans.
 Mr. G. M. Allen. Notes on the reptiles and amphibians of Intervale, N. H. (By title.)
 Dr. B. L. Robinson and Mr. J. M. Greenman. Contributions from the Gray herbarium of Harvard university, no. 17. (By title.)
 Dr. Gary de N. Hough. Studies in Diptera Cyclorhapha. (By title.)
 Mr. F. N. Balch. List of marine Mollusca of Cold Spring Harbor, Long Island, with descriptions of one new genus and two new species of nudibranchs. (By title.)
 Prof. G. E. Stone. The flora of Lake Quinsigamond. (By title.)

PUBLICATIONS.

The following publications have been issued during the year:—
 Localized stages in development in plants and animals, by Robert T. Jackson. *Memoirs*, vol. 5, no. 4, 65 pp., 10 plates, 5 cuts.
 The development, structure, and affinities of the genus *Equisetum*, by Edward C. Jeffrey. *Memoirs*, vol. 5, no. 5, 36 pp., 5 plates.
 The genus *Antennaria* in New England, by Merrit L. Fernald. *Proceedings*, vol. 28, no. 8, 13 pp.
 Notes on a Carboniferous boulder train in eastern Massachusetts, by Myron L. Fuller. *Proceedings*, vol. 28, no. 9, 14 pp., 1 cut.

On the veins of the Wolfian bodies in the pig, by Charles S. Minot. Proceedings, vol. 28, no. 10, 10 pp., 1 plate, 1 cut.

Proceedings of the annual meeting, May 4, 1898. Proceedings, vol. 28, no. 11, 26 pp.

The odonate genus *Macrothemis* and its allies, by Philip P. Calvert. Proceedings, vol. 28, no. 12, 32 pp., 2 plates.

Some hydroids from Puget Sound, by Gary N. Calkins. Proceedings, vol. 28, no. 13, 35 pp., 6 plates.

North American wood frogs, by Reginald Heber Howe, Jr. Proceedings, vol. 28, no. 14, 6 pp.

Studies in the gold-bearing slates of Nova Scotia, by J. Edmund Woodman. Proceedings, vol. 28, no. 15, 33 pp., 3 plates, 1 cut.

Moniloporidæ, a new family of Palæozoic corals, by Amadeus W. Grabau. Proceedings, vol. 28, no. 16, 16 pp., 4 plates.

LIBRARY.

The additions to the library have been as follows:—

	8vo.	4to.	Folio.	Total.
Volumes	278	31		309
Parts	2,208	373	1	2,582
Pamphlets	651	26	25	702
Maps			45	45
Total	3,137	430	71	3,638

The library contains 24,879 volumes, 1,378 incomplete (including current) volumes, and 12,812 pamphlets.

By exchange, gift, or purchase we have added twenty-eight serials:—Agricultural experiment stations of California, Connecticut, Delaware, Florida, Georgia, Illinois, Maine, Maryland, Minnesota, New Mexico, Rhode Island, and South Carolina; Bird lore; Blue Hill observatory bulletin; Bulletin Cooper ornithological club, Santa Clara; Kansas university geological survey; Lloyd mycological museum, Cincinnati; Mineral collector, New York; The museum, Albion, N. Y.; Natural history association of Miramichi, Chatham, N. B.; Nature study in school, West Newton; Naturwissenschaftliche gesellschaft in Winterthur, Winterthur; Ottawa literary and scientific society, Ottawa; Pasadena academy of sciences, Pasadena; Queensland agricultural journal, Brisbane;

Rhodora, Boston; Washington academy of science, Washington; Yorkshire naturalists' union, Leeds.

The Society now exchanges its publications with 482 scientific institutions and periodicals.

One thousand and thirty-seven books have been borrowed by 115 persons; 480 volumes have been borrowed for use in the building, and the library has been consulted 450 times.

Three hundred and sixty-eight volumes have been bound in 324 covers; 362 pamphlets have been bound.

Twenty-five volumes of the *Verhandlungen zoologisch-botanische gesellschaft, Wien*, have been indexed; current volumes of serials previously indexed are indexed as received.

Taking advantage of the aid afforded by a generous though anonymous patron, we have bound all the unbound books and pamphlets on several alcoves in the back library; the alcoves selected being those nearest the windows and thus the most exposed to light and dust.

WALKER PRIZES.

The subjects selected by the Walker Prize Committee for 1899 were: —

1. Is there fundamental difference between 'equation division' and 'reduction division' in the division of cells?
2. The phenomena and laws of hybridization.

The only essay received, one on the relations between the hybrid and parent forms of echinoid larvae, having been published in *Philosophical transactions of the royal society of London*, could not be considered by the Committee, as in all cases the memoirs are to be based upon original and unpublished work.

It is greatly to be regretted that the annual awards of Walker prizes are so frequently omitted, and it is suggested that the selection of subjects of broader scope would secure more general competition.

The subjects for the award in May, 1900, are: —

1. Stratigraphy and correlation of the sedimentary formations of any part of New England.
2. A study in palaeozoic stratigraphy and correlation.

REPORT OF THE TREASURER, EDWARD T. BOUVÉ.

ANNUAL STATEMENT, MAY 3, 1898. BOSTON SOCIETY OF NATURAL HISTORY,

To cash received from income General Fund.....	\$5,481.46	By cash paid on account of Repairs.....	\$ 604.60
" " " Walker Fund.....	2,153.77	" " " Fuel and Gas.....	288.05
" " " J. W. Randall Fund.....	250.00	" " " Insurance.....	780.00
" " " H. F. Wolcott Fund.....	233.92	" " " General Expense.....	1,187.22
" " " Entomological Fund.....	26.00	" " " Salaries.....	8,476.00
" " " C. L. Flint Fund.....	237.26	" " " Laboratory.....	50.96
" " " Bulfinch St. Estate Fund.....	1,305.77	" " " Museum.....	714.19
" " " S. P. Pratt Fund.....	649.17	" " " Library.....	929.66
" " " Boston University.....	3,500.00	" " " Publications.....	1,097.24
" " " Massachusetts Inst. Technology..	200.00	" " " Walker Prizes (advertising)	21.81
" " " Admission Fees.....	360.00	" " Trustees for Walker Fund.....	37.76
" " " Annual Assessments.....	1,160.00	" " Secretary for Publication acct. (balance	1,096.42
" " " Museum Fees.....	318.19	appropriations voted by Council)...	
" " " Sale of Publications.....	189.57		
" " " General expense credits.....	38.00		
" " " Insurance Sinking Fund.....	280.00		
Total,	\$15,283.01	Total,	\$15,283.01
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To cash received from Augustus Lowell, Trustee for the		By cash paid on account of Lectures and Supplies.....	\$2,723.40
Teachers' School of Science.....	\$3,450.00	Balance to new account.....	122.98
To cash received from Interest on deposit and tickets			
sold.....	9.29		
Balance from April 30, 1898.....	387.09		
Total,	\$2,846.38	Total,	\$2,846.38
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To cash received from Mrs. J. M. Arms Sheldon.....	\$ 400.00	By cash paid for services and supplies.....	\$ 228.97
" " " Interest on deposit.....	7.47	Balance to new account.....	1,029.23
Balance from April 30, 1898.....	850.78		
Total,	\$1,258.25	Total,	\$1,258.25

The reports of the Trustees and of the Auditing Committee were read and it was voted to accept and adopt the several reports.

The Society then proceeded to ballot for officers for 1899-1900. Messrs. R. P. Bigelow and R. Hayward were appointed to collect and count the votes. They reported the election of

PRESIDENT,

CHARLES SEDGWICK MINOT.

VICE-PRESIDENTS,

CHARLES P. BOWDITCH.

HENRY W. HAYNES.

WILLIAM G. FARLOW.

CURATOR,

ALPHEUS HYATT.

SECRETARY,

SAMUEL HENSHAW.

TREASURER,

EDWARD T. BOUVÉ.

LIBRARIAN,

SAMUEL HENSHAW.

COUNCILLOR FOR THREE YEARS,

MISS CORA H. CLARKE.

GEORGE H. PARKER.

ROBERT T. JACKSON.

A. LAWRENCE ROTCH.

J. ARNOLD LOWELL.

WILLIAM F. WHITNEY.

EDWARD S. MORSE.

J. B. WOODWORTH.

COUNCILLOR FOR ONE YEAR,

H. C. BUMPUS.

OFFICERS FOR 1899-1900.

PRESIDENT,

CHARLES SEDGWICK MINOT.

VICE-PRESIDENTS,

CHARLES P. BOWDITCH.

HENRY W. HAYNES.

WILLIAM G. FARLOW.

CURATOR,

ALPHEUS HYATT.

SECRETARY,

SAMUEL HENSHAW.

TREASURER,

EDWARD T. BOUVÉ.

LIBRARIAN,

SAMUEL HENSHAW.

COUNCILLORS FOR THREE YEARS,

MISS CORA H. CLARKE.

GEORGE H. PARKER.

ROBERT T. JACKSON.

A. LAWRENCE ROTCH.

J. ARNOLD LOWELL.

WILLIAM F. WHITNEY.

EDWARD S. MORSE.

J. B. WOODWORTH.

COUNCILLORS FOR TWO YEARS,

CHARLES B. DAVENPORT.

AUGUSTUS LOWELL.

JAMES H. EMERTON.

MISS SUSANNAH MINNS.

WILLIAM A. JEFFRIES.

THOMAS A. WATSON.

GEORGE G. KENNEDY.

SAMUEL WELLS.

COUNCILLORS FOR ONE YEAR,

S. L. ABBOT.

MISS CATHARINE I. IRELAND.

WILLIAM S. BRYANT.

BENJAMIN JOY JEFFRIES.

H. C. BUMPUS.

N. T. KIDDER.

WILLIAM M. DAVIS.

WILLIAM H. NILES.

COUNCILLORS *ex-officio*,

GEORGE L. GOODALE.

F. W. PUTNAM.

SAMUEL H. SCUDDER.

LIST OF MEMBERS.

HONORARY MEMBERS.

Alexander Agassiz,	Cambridge.
Adolph Bastian,	Berlin.
John William Dawson,	Montreal.
Michael Foster,	Cambridge.
Ernst Haeckel,	Jena.
Joseph D. Hooker,	London.
Albert v. Kölliker,	Würzburg.
Henri Lacaze-Duthiers,	Paris.
Edward B. Tylor,	London.
Rudolph Virchow,	Berlin.

CORRESPONDING MEMBERS.

William Allen,	Boston.
James Anderson,	Liverpool, Eng.
Francis Archer,	Liverpool, Eng.
Francesco Ardissoni,	Milan, Italy.
Loring W. Bailey,	Fredericton, N. B.
A. S. Baldwin,	Jacksonville, Fla.
Mariano Barcena,	Mexico, Mex.
A. Constantine Barry,	Prairie du Sac, Wis.
Charles E. Beecher,	New Haven, Ct.
Hermann Behr,	San Francisco, Cal.
E. van Beneden,	Liège, Belgium.
William G. Binney,	Burlington, N. J.
Nathaniel H. Bishop,	Lake George, N. Y.
William P. Blake,	New Haven, Ct.
George A. Boardman,	Calais, Me.
William H. Brewer,	New Haven, Ct.
William K. Brooks,	Baltimore, Md.
John Brown,	New York, N. Y.
Giovanni Capellini,	Bologna, Italy.
Antonio del Castillo,	Mexico, Mex.
Ferdinand Cohn,	Breslau, Germany.
Guido Cora,	Rome, Italy.

26 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Elliott Coues,
John M. Coulter,
Hermann Credner,
Ezra T. Cresson,
Josiah Curtis,

Henry Davis,
William Boyd Dawkins,
William Dean,
Anton Dohrn,
Sanford B. Dole,
Henry E. Dresser,
Paul B. Du Chaillu,
W. T. T. Dyer,

Arthur M. Edwards,
William H. Edwards,
D. G. Elliot,
Sigmund Exner,

Roswell Field,
William H. Flower,
F. Fouqué,

M. Ganin,
J. T. Gardner,
Albert Gaudry,
Archibald Geikie,
James Geikie,
Hans B. Geinitz,
Theodore N. Gill,
Augustus R. Grote,
Albert C. L. G. Günther,
John T. Gulick,
L. H. Gulick,

Edwin Harrison,
James Hector,
Angelo Heilprin,
George Henslow,
Henry Y. Hind,
Charles H. Hitchcock,
John Hjaltalin,
W. J. Hoffman,
W. J. Holland,
Bernard A. Hoopes,
A. W. Howitt,
Oliver P. Hubbard,
Samuel Hubbard,

Washington, D. C.
Chicago, Ill.
Leipsic, Germany.
Philadelphia, Pa.
Washington, D. C.

McGregor, Iowa.
Manchester, Eng.
Bangkok, Siam.
Naples, Italy.
Honolulu, H. I.
Kent, Eng.
New York, N. Y.
London, Eng.

Newark, N. J.
Coalburg, W. Va.
Chicago, Ill.
Vienna, Austria.

Gill.
London, Eng.
Paris, France.

Nice, France.
Washington, D. C.
Paris, France.
Edinburgh, Scotland.
Edinburgh, Scotland.
Dresden, Germany.
Washington, D. C.
Hildesheim, Germany.
London, Eng.
Osaka, Japan.
Honolulu, Oahu.

St. Louis, Mo.
Wellington, N. Z.
Philadelphia, Pa.
London, Eng.
Windsor, N. S.
Hanover, N. H.
Rejkyavik, Iceland.
Reading, Pa.
Alleghany, Pa.
Philadelphia, Pa.
Melbourne, Vict.
Hanover, N. H.
San Francisco, Cal.

Christopher Johnson, David S. Jordan,	Baltimore, Md. Leland Stanford, Cal.
Clarence King, John King, Cornelius Kollock, A. Kowalewsky, Carl Kupffer,	Washington, D. C. Boone, Iowa. Cheraw, S. C. St. Petersburg, Russia. Munich, Germany.
Arnold Lang, E. Ray Lankester, Joseph Leconte, R. von Lendenfeld, J. Peter Lesley, A. M. Lévy, F. W. Lewis, Franz Leydig, Christian F. Lütken, Richard Lydekker,	Zurich, Switzerland. London, Eng. Berkeley, Cal. Czernowitz, Austria. Milton. Paris, France. Philadelphia, Pa. Bonn, Germany. Copenhagen, Denmark. Harpenden, Eng.
Robert McLachlan, E. J. Marey, Paul Mayer, Joseph B. Meader, C. Hart Merriam, Charles L. Metz, Alphonse Milne-Edwards, S. Wier Mitchell, John Murray,	London, Eng. Paris, France. Naples, Italy. Stoneham. Washington, D. C. Madisonville, Ohio. Paris, France. Philadelphia, Pa. Edinburgh, Scotland.
Francis P. Nash, Alfred Newton,	Geneva, N. Y. Cambridge, Eng.
Henry F. Osborn, C. R. von Osten Sacken, Emile Oustalet,	New York, N. Y. Heidelberg, Germany. Paris, France.
Thomas F. Perley, Félix Plateau, Edward B. Poulton, John W. Powell, Raphael Pumpelly,	Portland, Me. Liège, Belgium. Oxford, Eng. Washington, D. C. Newport, R. I.
Richard Rathbun, Ferd von Richthofen, Robert Ridgway, Heinrich Rosenbusch,	Washington, D. C. Bonn, Germany. Washington, D. C. Heidelberg, Germany.
Henri de Saussure, C. M. Scammon,	Geneva, Switzerland. Washington, D. C.

28 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Philip L. Slater,
A. R. C. Selwyn,
William Sharswood,
Hamilton L. Smith,
Hermann Snellen,

Armand Thielens,
Tamerlan Thorell,
William Trelease,
Gustav Tschermak,

Philip R. Uhler,

Addison E. Verrill,
Sydney H. Vines,

W. Waagen,
Henry A. Ward,
R. A. Ward,
Carl Wedt,
August Weismann,
George M. Wheeler,
William T. White,
R. P. Whitfield,
Robert E. E. Wiedersheim,
Burt G. Wilder,
C. S. Wilkinson,
Edmund B. Wilson,
Henry Woodward,
J. J. Woodward,

Ferdinand Zirkel,
Carl A. Zittel,

London, Eng.
Ottawa, Can.
Philadelphia, Pa.
Geneva, N. Y.
Utrecht, Holland.

Tirlemont, Belgium.
Montpellier, France.
St. Louis, Mo.
Vienna, Austria.

Baltimore, Md.

New Haven, Ct.
Oxford, Eng.

Vienna, Austria.
Rochester, N. Y.
Troy, N. Y.
Vienna, Austria.
Freiburg, Germany.
Washington, D. C.
New York, N. Y.
New York, N. Y.
Freiburg, Germany.
Ithaca, N. Y.
Sydney, N. S. W.
New York, N. Y.
London, Eng.
Washington, D. C.

Leipsic, Germany.
Munich, Germany.

CORPORATE MEMBERS.

Samuel L. Abbot, M. D.,
John E. Alden,
Jane Alexander,
Henry F. Allen,
Joel A. Allen,
Edward P. Allis, Jr.,
Arthur Amory,
Robert Amory, M. D.,
S. Reed Anthony,
Nathan Appleton,
William S. Appleton,
Annetta F. Armes,
Edward P. Austin,

90 Mt. Vernon St.
Newton.
91 Mt. Vernon St.
Jamaica Plain.
Absent.
Milwaukee, Wis.
133 Marlborough St.
279 Beacon St.
53 State St.
Somerset Club.
462 Beacon St.
Dorchester.
Absent.

Lucas Baker,	Absent.
Francis N. Balch,	Jamaica Plain.
Edward E. Bancroft, M. D.,	Wellesley.
Edward A. Bangs,	240 Beacon St.
Outram Bangs,	240 Beacon St.
James M. Barnard,	Milton.
Walter B. Barrows,	Absent.
George H. Barton,	Mass. Inst. of Technology.
Charles F. Batchelder,	Cambridge.
George W. Beaman,	Absent.
Mrs. George W. Beaman,	Cambridge.
Henry B. Bigelow,	251 Commonwealth Ave.
Joseph S. Bigelow, Jr.,	251 Commonwealth Ave.
Robert P. Bigelow,	Mass. Inst. of Technology.
William S. Bigelow, M. D.,	60 Beacon St.
Clarence J. Blake, M. D.,	226 Marlborough St.
Francis Blake,	Auburndale.
James H. Blake,	Cambridge.
Joseph W. Blankinship,	Bozeman, Mont.
Albert N. Blodgett, M. D.,	51 Massachusetts Ave.
Mrs. Alice L. Boardman,	Absent.
Elizabeth D. Boardman,	416 Marlborough St.
Edward T. Bouvé,	436 Marlborough St.
Charles P. Bowditch,	28 State St.
Frederic C. Bowditch,	Brookline.
Henry P. Bowditch, M. D.,	Harvard Medical School.
Mrs. Ella F. Boyd,	Hyde Park.
Arthur C. Boyden,	Bridgewater.
Francis W. Brewer,	Hingham.
Mrs. Thomas M. Brewer,	233 Beacon St.
Willard S. Brewer,	Hingham.
Edwin T. Brewster,	Andover.
William Brewster,	Cambridge.
Albert P. Brigham,	Absent.
Henry Brooks,	Lincoln.
Shepherd Brooks,	92 Beacon St.
J. Frank Brown,	89 State St.
Edward I. Browne,	53 State St.
Elizabeth B. Bryant,	Allston.
John Bryant, M. D.,	Cohasset.
William S. Bryant, M. D.,	53 State St.
Charles Bullard,	Cambridge.
William N. Bullard, M. D.,	89 Marlborough St.
Hermion C. Bumpus,	Providence, R. I.
Arthur T. Cabot, M. D.,	1 Marlborough St.
Edward C. Cabot,	Brookline.
Louis Cabot,	Brookline.

30 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

William B. Cabot,
 Mrs. Gary N. Calkins,
 Alvin Carl,
 Charles T. Carruth,
 Mrs. J. B. Case,
 Arthur P. Chadbourne, M. D.,
 Montague Chamberlain,
 Walter G. Chase,
 Francis S. Child,
 Henry L. Clapp,
 Mabel D. Clapp,
 John S. Clark,
 T. W. B. Clark,
 Cora H. Clarke,
 Collier Cobb,
 Edward W. Codman,
 Helen Collamore,
 Frank S. Collins,
 Grace E. Cooley,
 Algernon Coolidge, M. D.,
 T. Jefferson Coolidge, Jr.,
 Mrs. Elizabeth R. Cormier,
 Charles B. Cory,
 Charles U. Cotting,
 Sarah H. Crocker,
 William O. Crosby,
 Charles R. Cross,
 Clara E. Cummings,

Ulric Dahlgren,
 William H. Dall,
 Reginald A. Daly,
 Ada Dana,
 John Dane,
 F. Graef Darlington,
 Charles B. Davenport,
 Andrew McF. Davis,
 James C. Davis,
 Simon Davis,
 William M. Davis,
 Henry G. Denny,
 Franklin Dexter, M. D.,
 F. Gordon Dexter,
 Gordon Dexter,
 Joseph S. Diller,
 George Dinmock,
 Richard E. Dodge,
 Charles C. Doe,

Chestnut Hill.
 New York, N. Y.
 Jamaica Plain.
 34 India St.
 468 Beacon St.
 225 Marlborough St.
 Cambridge.
 Brookline.
 Absent.
 Roxbury.
 9 Massachusetts Ave.
 646 Washington St.
 326 Atlantic Ave.
 91 Mt. Vernon St.
 Chapel Hill, N. C.
 53 Marlborough St.
 317 Commonwealth Ave.
 Malden.
 Wellesley.
 81 Marlborough St.
 184 Beacon St.
 Charlestown.
 160 Boylston St.
 249 Commonwealth Ave.
 319 Commonwealth Ave.
 Mass. Inst. of Technology.
 Mass. Inst. of Technology.
 Wellesley.

Princeton, N. J.
 Absent.
 Absent.
 Newton.
 29 Marlborough St.
 Absent.
 Cambridge.
 Cambridge.
 70 Kilby St.
 277 Beacon St.
 Cambridge.
 68 Devonshire St.
 148 Marlborough St.
 55 Beacon St.
 55 Beacon St.
 Absent.
 Springfield.
 Absent.
 South Newbury, Vt.

Thomas Doliber,
Jonathan Dorr,
George A. Dorsey,
Richard S. Dow,
Sara A. Downs,
Thomas Dwight, M. D.,
Harrison G. Dyar,

Brookline.
27 School St.
Chicago, Ill.
27 State St.
58 Berkeley St.
235 Beacon St.
Washington, D. C.

Raymond B Earle,
Charles R. Eastman,
Charles W. Eliot,
Mrs. J. W. Elliot,
Mary L. Ells,
James H. Emerton,
William Endicott,
Harold C. Ernst, M. D.,
James F. Estes,

Newton.
Cambridge.
Cambridge.
124 Beacon St.
Cambridge.
Clarendon St.
33 Summer St.
Harvard Medical School.
Absent.

William G. Farlow, M. D.,
Mrs. Eva D. Farquhar,
Charles E. Faxon,
Henry H. Fay,
Joseph S. Fay,
Charles S. Fellows,
Charles H. Fernald,
J. Walter Fewkes,
William L. W. Field,
Frank S. Fiske,
George W. Fitz, M. D.,
Augustus Flagg,
Charles F. Folsom, M. D.,
Justus W. Folsom,
Eugene N. Foss,
John Foster,
William Foster,
Harriet E. Freeman,
Nathaniel S. French,
Sophia W. French,
Charles Fry,
Myron L. Fuller,
Sarah S. Fuller,

Cambridge.
Roxbury.
Jamaica Plain.
416 Beacon St.
169 Commonwealth Ave.
Fairbanks, Fla.
Amherst.
Absent.
Milton.
U. S. Court House.
Cambridge.
274 Clarendon St.
15 Marlborough St.
Cambridge.
Jamaica Plain.
113 Broad St.
Absent.
384 Commonwealth Ave.
West Roxbury.
Wollaston.
21 Commonwealth Ave.
Mass. Inst. of Technology.
Absent.

Thomas Gaffield,
Charles W. Galloupe,
T. W. Galloway,
William F. Ganong,
Edward G. Gardiner,
John L. Gardner, Jr.,

54 Allen St.
45 Broad St.
Marshall, Mo.
Absent.
131 Mt. Vernon St.
51 Commonwealth Ave.

32 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

George M. Garland, M. D.,
George W. Gay, M. D.,
B. W. Gilbert,
George L. Goodale, M. D.,
Harold B. Goodrich,
Mrs. Mary T. Gorham,
Amadeus W. Grabau,
Francis C. Gray,
John C. Gray,
Robert W. Greenleaf, M. D.,
Mrs. C. W. Greenough,
Charles P. Greenough,
H. S. Greenough,
William D. Grier,
Leon S. Griswold,

Minna B. Hall,
Robert W. Hall,
Susan M. Hallowell,
Mrs. M. L. Hammatt,
Ida S. Hammerle,
Edward D. Harris,
T. W. Harris,
Francis R. Hart,
Franklin Haven,
Gustavus Hay, M. D.,
Ellen Hayes,
Henry W. Haynes,
Roland Hayward,
Charles E. Hellier,
Augustus Hemenway,
Mrs. Augustus Hemenway,
Joseph P. B. Henshaw,
Samuel Henshaw,
Warren W. Herman,
Francis H. Herrick,
Ella J. Hill,
Harriet A. Hill,
Hibbert W. Hill, M. D.,
Mary H. Hinckley,
John Hobbs,
Walter E. Hobbs,
John Hogg,
Frederick S. Hollis,
John Homans, M. D.,
Robert C. Hooper,
Mrs. S. E. Hooper,
Samuel A. Hopkins, M. D.,

227 Newbury St.
665 Boylston St.
202 Purchase St.
Cambridge.
72 Westland Ave.
108 Marlborough St.
Cambridge.
7 Mt. Vernon Place.
176 Beacon St.
561 Boylston St.
Jamaica Plain.
39 Court St.
Absent.
20 Kilby St.
Dorchester.

Brookline.
Cambridge.
Wellesley.
Hyde Park.
Roxbury.
Absent.
Absent.
Milton.
97 Mt. Vernon St.
383 Marlborough St.
Wellesley.
239 Beacon St.
346 Marlborough St.
57 Equitable Bldg.
273 Clarendon St.
273 Clarendon St.
77 Newbury St.
Cambridge.
P. O. Box 1848.
Cleveland, Ohio.
223 Newbury St.
Belmont.
72 Pinckney St.
Mattapan.
99 St. Botolph St.
Stonybrook.
280 Commonwealth Ave.
Newton Highlands.
164 Beacon St.
448 Beacon St.
Cambridge.
235 Marlborough St.

Garry de N. Hough, M. D.,
Theodore Hough,
Helen Hubbard,
John G. Hubbard,
L. L. Hubbard,
John E. Hudson,
Henry S. Hunnewell,
Willard P. Hunnewell,
Alpheus Hyatt,

Charles E. Inches, M. D.,
Catherine I. Ireland,

John G. Jack,
John C. Jackson,
Robert T. Jackson,
William D. Jackson,
Thomas A. Jaggar, Jr.,
B. Joy Jeffries, M. D.,
William A. Jeffries,
Charles W. Jenks,
Charles F. Jenney,
Isabel L. Johnson,
Samuel Johnson,
Marian H. Judd,

Charles S. Kendall,
Mrs. Caroline A. Kennard,
George G. Kennedy, M. D.,
Harris Kennedy, M. D.,
Nathaniel T. Kidder,
John S. Kingsley,

F. D. Lambert,
Alfred C. Lane,
Amory A. Lawrence,
William Lawrence,
George W. Lee,
David F. Lincoln, M. D.,
James L. Little,
William R. Livermore,
William C. Loring,
Augustus Lowell,
Charles Lowell,
James Arnold Lowell,
Mrs. Louisa F. Lowery,
Arthur T. Lyman,
Charles P. Lyman, M. D.,

New Bedford.
Mass. Inst. of Technology.
Charlestown, N. H.
Brookline.
Absent.
125 Milk St.
9 Park St.
261 Commonwealth Ave.
Cambridge.

386 Beacon St.
Cambridge.

Jamaica Plain.
Absent.
33 Gloucester St.
Bridgewater.
Cambridge.
15 Chestnut St.
126 Beacon St.
Bedford.
Hyde Park.
467 Massachusetts Ave.
7 Commonwealth Ave.
186 Commonwealth Ave.

91 Federal St.
Brookline.
Readville.
Readville.
Milton.
Tufts College.

Auburn, Me.
Houghton, Mich.
59 Commonwealth Ave.
122 Commonwealth Ave.
Brookline.
73 Pinckney St.
Brookline.
P. O. Box 168.
2 Gloucester St.
53 State St.
149 Beacon St.
297 Beacon St.
Absent.
P. O. Box 1717.
50 Village St.

34 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

George H. Mackay,	218 Commonwealth Ave.
W. Duncan McKim,	Portsmouth, N. H.
J. Playfair McMurrich,	Absent.
W. D. McPherson,	South Framingham.
B. Pickman Mann,	Absent.
Warren H. Manning,	Brookline.
Edward L. Mark,	Cambridge.
Mrs. W. H. K. Marra,	Absent.
Vernon F. Marsters,	Bloomington, Ind.
Asa E. Mattice,	Concord, Mich.
F. W. G. May,	Dorchester.
Alfred G. Mayer,	Cambridge.
Charles J. Maynard,	West Newton.
James Means,	196 Beacon St.
James C. Merrill, M. D.,	Absent.
Selah Merrill,	Absent.
Gerrit S. Miller, Jr.,	Washington, D. C.
Susannah Minns,	14 Louisburg Sq.
Charles S. Minot,	Harvard Medical School.
Laurence Minot,	24 Marlborough St.
William Minot,	39 Court St.
George Mixter,	219 Beacon St.
William J. Moenkhaus,	Williamstown.
Henry L. Moody,	Absent.
Alexander Moore,	3 School St.
Margaret W. Morley,	28 St. James Ave.
Albro D. Morrill,	Clinton, N. Y.
Albert P. Morse,	South Natick.
Edward S. Morse,	Salem.
Elisha W. Morse,	Jamaica Plain.
John Murdoch,	Roxbury.
Albert L. Murdock,	15 Causeway St.
Nathaniel C. Nash,	Cambridge.
Herbert V. Neal,	Absent.
Frederick H. Newell,	Absent.
Mrs. Edith J. Nichols,	294 Marlborough St.
Sereno D. Nickerson,	Masonic Temple.
William H. Niles,	Cambridge.
Grenville H. Norcross,	9 Commonwealth Ave.
Edward E. Norton,	419 Washington St.
William E. Norton,	Absent.
John Orne, Jr.	Cambridge.
Alpheus S. Packard, M. D.,	Providence, R. I.
George H. Parker,	Cambridge.
Edith A. Parkhurst,	Somerville.
George L. Parmelee,	Absent.

William Patten,
 Francis H. Peabody,
 James E. Peabody,
 Edward C. Perkins,
 William H. Phelps,
 John C. Phillips,
 Dudley L. Pickman,
 David Pingree,
 Julia B. Platt,
 William G. Preston,
 Frances C. Prince,
 Loring W. Puffer,
 Charles P. Putnam, M. D.,
 Frederick W. Putnam,
 James J. Putnam, M. D.,

Hanover, N. H.
 113 Devonshire St.
 Absent.
 706 Sears Bldg.
 Absent.
 299 Berkeley St.
 98 Beacon St.
 Salem.
 Absent.
 186 Devonshire St.
 17 Joy St.
 Brockton.
 63 Marlborough St.
 Cambridge.
 106 Marlborough.

Motte A. Read,
 Mrs. William H. Reed,
 John P. Reynolds, M. D.,
 Stephen H. Rhodes,
 Mrs. Ellen H. Richards,
 George H. Richards,
 Harriet E. Richards,
 Robert H. Richards,
 William L. Richardson, M. D.,
 Everett W. Ricker,
 William Z. Ripley,
 Thomas P. Ritchie,
 Benjamin L. Robinson,
 Alfred P. Rockwell,
 Mrs. William B. Rogers,
 A. Lawrence Rotch,
 William H. Ruddick, M. D.,
 Mrs. T. E. Ruggles,
 John D. Runkle,
 Frederick W. Russell, M. D.,

Absent.
 37 Commonwealth Ave.
 416 Marlborough St.
 541 Commonwealth Ave.
 Jamaica Plain.
 14 Chestnut St.
 Boston.
 Jamaica Plain.
 225 Commonwealth Ave.
 City Hall.
 Mass. Inst. of Technology.
 Newton Highlands.
 Cambridge.
 281 Beacon St.
 117 Marlborough St.
 53 State St.
 502 E. Broadway.
 Milton.
 Mass. Inst. of Technology.
 Winchendon.

William E. Safford,
 Lilian V. Sampson,
 Charles S. Sargent,
 Dudley A. Sargent, M. D.,
 Frederick Le R. Sargent,
 Mrs. Marian E. Y. Saville,
 Marshall H. Saville,
 Henry Sayles,
 Alfred L. T. Schaper, M. D.,
 Barthold Schlesinger,
 Samuel H. Scudder,

Absent.
 Germantown, Pa.
 Brookline.
 Cambridge.
 Absent.
 Waban.
 Absent.
 Somerset Club.
 Harvard Medical School.
 131 Devonshire St.
 Cambridge.

John H. Sears,	Salem.
Mrs. Mary L. Seavey,	Brookline.
William T. Sedgwick,	Mass. Inst. of Technology.
Nathaniel S. Shaler,	Cambridge.
J. C. Sharp, Jr.,	54 Commonwealth Ave.
Stephen P. Sharples,	13 Broad St.
Mrs. J. M. Sheldon,	108 Mt. Vernon St.
Augustine Shurtleff, M. D.,	Brookline.
A. D. Sinclair, M. D.,	35 Newbury St.
Charles C. Smith,	286 Marlborough St.
Frederic F. Smith,	Springfield.
Caroline G. Soule,	Brookline.
Edmund D. Spear, M. D.,	20 Mt. Vernon St.
A. W. Spencer,	31 State St.
Charles J. Sprague,	380 Marlborough St.
Frank F. Stanley,	108 Summer St.
George E. Stone,	Amherst.
Charles S. Street,	Absent.
Mrs. Charles P. Strong,	Cambridge.
William C. Sturgis,	New Haven, Conn.
John O. Sumner,	Absent.
Charles W. Swan, M. D.,	Brookline.
J. Brooks Taft,	28 Pemberton Sq.
Ralph S. Tarr,	Absent.
Levi L. Thaxter,	13 Tremont St.
Roland Thaxter,	Cambridge.
John E. Thayer,	Lancaster.
Mary F. Thompson,	413 Shawmut Ave.
Augustus L. Thorndike,	722 Tremont Bldg.
Townsend W. Thorndike,	22 Newbury St.
G. Francis Topliff,	48 Congress St.
Mrs. Helen M. Tower,	Cambridgeport.
Samuel F. Tower,	English High School.
William L. Tower,	Cambridge.
W. Porter Truesdell,	12 South St.
Frederick Tuckerman, M. D.,	Amherst.
William Tudor,	Absent.
Warren Upham,	Absent.
J. F. Urie, M. D.,	Absent.
Balfour H. Van Vleck,	Boston Soc. of Nat. Hist.
T. Wayland Vaughan,	Absent.
M. Edward Wadsworth,	Absent.
Oliver F. Wadsworth, M. D.,	526 Beacon St.
Robert Wainwright,	Absent.

Frederick C. Waite,	New York, N. Y.
Mary L. Ware,	41 Brimmer St.
Joseph W. Warren, M. D.,	Absent.
Mrs. Elizabeth S. Watson,	Weymouth.
Thomas A. Watson,	Weymouth.
Mary M. Webster,	232 Newbury St.
Clarence M. Weed,	Durham, N. H.
Andrew G. Weeks,	400 Beacon St.
Andrew G. Weeks, Jr.,	360 Washington St.
Charles G. Weld, M. D.,	6 Commonwealth Ave.
Samuel M. Weld,	North Chatham.
Samuel Wells,	45 Commonwealth Ave.
William P. Wesselhoeft, M. D.,	176 Commonwealth Ave.
Arthur W. Weysee,	Mass. Inst. of Technology.
Mrs. Katharine K. Wheeler,	Roxbury.
Charles T. White,	213 Commonwealth Ave.
James C. White, M. D.,	259 Marlborough St.
Charles O. Whitman,	Chicago, Ill.
Henry M. Whitney,	107 Commonwealth Ave.
Solon F. Whitney,	Watertown.
William F. Whitney, M. D.,	228 Marlborough St.
W. H. Whittlemore,	Milford, N. H.
George Wigglesworth,	53 State St.
Thomas Wigglesworth,	36 Hawley St.
Mary A. Willcox,	Wellesley.
Emile F. Williams,	352 Massachusetts Ave.
Henry V. Wilson,	Chapel Hill, N. C.
William P. Wilson,	Absent.
Clifton E. Wing, M. D.,	Roxbury.
Guy M. Winslow,	Auburndale.
Roger Wolcott,	173 Commonwealth Ave.
John E. Wolff,	Cambridge.
Edward S. Wood, M. D.,	Harvard Medical School.
Elvira Wood,	Mass. Inst. of Technology.
J. Edmund Woodman,	Cambridge.
Frederick A. Woods, M. D.,	Brookline.
Jay B. Woodworth,	Cambridge.
William McM. Woodworth,	Cambridge.
G. Frederick Wright,	Oberlin, Ohio.
E. Bentley Young,	104 Appleton St.
Francis Zirngiebel,	Roxbury.

PATRONS.

Loring W. Bailey.
W. W. Bailey.
James M. Barnard.
Miss Emeline Binney.
Mrs. Mary G. P. Binney.

George R. Carter.
Henry Cross.

C. W. Galloupe.

Nathan Matthews.
John J. May.
Samuel May.

Henry Sayles.
Mrs. G. H. Shaw.
Charles J. Sprague.
W. W. Stone.

Thomas Wigglesworth.
Edward Wyman.

BY-LAWS.

SECTION 1. MEMBERS.

1. The Society shall consist of Corporate Members, Corresponding Members, Honorary Members, and Patrons.

2. Members shall be elected by the Council only upon the recommendation of the Committee on Membership. Nominations must be in writing and endorsed by two Members. Corporate Members and Patrons only shall be entitled to vote, to transact business, or to hold office.

3. Corresponding and Honorary Members may be chosen from among persons who have contributed to the advancement of science on whom the Society may wish to confer a mark of respect.

4. Members may withdraw from the Society by giving written notice of such intention and paying all arrears. Members who have neglected to pay their regular assessments for two successive years, and have received due notification thereof from the Treasurer, shall become liable to forfeit their membership at any time when the Council shall so order.

5. A Member may be expelled from the Society upon the recommendation of the Council, by a vote of three fourths of the

Members present at a meeting of the Society after notice of such proposed action has been sent to all Corporate Members at least four days before such meeting.

6. Any person who contributes at one time, to the funds of the Society, a sum not less than five hundred dollars shall become a Patron.

SECTION 2. ADMISSION FEE AND ASSESSMENTS.

1. Every person elected a Corporate Member, before obtaining the privileges of membership, must pay an admission fee of five dollars.

2. Every Corporate Member shall be subject to an annual assessment of five dollars payable on the first day of October in each year, but for one hundred dollars life membership may be granted free from annual assessment.

3. Members who have given notice that they will be unable to avail themselves of the privileges of membership for an entire year dating from October 1 shall be exempt from the payment of the assessment for that year.

4. The President and Treasurer shall be empowered to return (*sub silentio*) to a Corporate Member the admission fee and the annual assessment, if they deem it for the interest of the Society to do so.

5. Corresponding and Honorary Members shall not be required to pay an admission fee or any assessment.

SECTION 3. NOMINATING COMMITTEE.

1. At the General Meeting held on the third Wednesday of March a Nominating Committee of five persons shall be appointed who shall report at the next meeting of the Society a list of candidates for the offices to be filled. Additional nominations may be made by any Corporate Member.

2. Unless otherwise ordered the Nominating Committee shall be appointed by the Chair.

3. No person shall be eligible for election to any office except after nomination at a preceding meeting.

SECTION 4. OFFICERS.

1. The officers of the Society shall be a President, three Vice-Presidents, a Curator, a Secretary, a Librarian, a Treasurer, and twenty-four Councillors, who together shall constitute a board for the management of the affairs of the Society, and shall be called the Council, and shall hold office until their successors have qualified in their places.

All Presidents and Vice-Presidents prior to January 7, 1891, are *ex-officio* members of the Council.

All officers shall be chosen by ballot. Of the twenty-four Councillors eight shall be chosen at each Annual Meeting to serve for three years.

2. The President shall preside at the meetings of the Society and of the Council.

3. The Vice-Presidents shall perform the duties of President in his absence in the order of seniority in office.

4. The Curator shall be a person of acknowledged scientific attainments. Under direction of the Council he shall have general charge of the museum and its contents, shall be responsible for the proper arrangement of the collections, and shall perform such other duties as may be prescribed by the Council.

5. The Secretary shall record the proceedings of the Society, of its Sections, and of the Council, in books to be kept for that purpose; shall have charge of all records belonging to the Society, and of its publications; shall conduct the correspondence of the Society, and keep a record thereof; shall inform Members of their election, and Committees of their appointment; and shall give notice of all meetings, and inform officers of all matters which occur at any meeting requiring their action.

6. The Librarian shall have charge of the library and shall observe and enforce such regulations as the Council may make for its use.

7. The Treasurer shall receive all moneys due or payable to the Society; shall pay all accounts against it when the same have been approved by the Executive Committee; and shall keep a correct account of all his receipts and expenditures in books belonging to the Society. He shall receive officially all moneys given or bequeathed to the Society, transmit the same to the Trustees, and report his action to the Council. When requested by the Council he shall make a detailed report of all his doings.

SECTION 5. COUNCIL.

1. The Council shall have full power to act for the interests of the Society, shall control all expenditures, and shall make rules for the use of the library and of the museum, and for the direction of the Curator, the Secretary, and the Treasurer.

2. The Annual Meeting of the Council shall be held on the second Wednesday in May, at which meeting a Board of three Trustees shall be elected to hold all the funded property of the Society in trust with power to sell and to reinvest according to their judgment. The following Standing Committees shall also be elected; viz.: an Executive Committee of five, in whom the affairs of the Council shall be vested so far as it shall determine by its votes and rules; a Membership Committee of five to recommend to the Council persons for election as Members; a Library and Publishing Committee of five to superintend the library and the issue and exchange of the publications of the Society; a Walker Prize Committee of three to have charge of matters relating to that foundation; and an Auditing Committee of two to audit the accounts of the Treasurer. These Committees and Boards need not be chosen from the Council, and they shall hold office until their successors have qualified.

Special committees also may be appointed if needed.

3. The Council may fill the vacancies occurring among the twenty-four Councillors until the next Annual Meeting of the Society.

SECTION 6. MEETINGS.

1. The Annual Meeting for the election of officers and for other general purposes shall be held on the first Wednesday in

May. At this meeting the following reports shall be presented: by the Curator upon the condition and progress of the museum, the lectures which he has superintended, and any other matters of general interest; by the Secretary upon the publications, meetings, and the lectures which he has superintended; by the Librarian upon the library; by the Treasurer upon the receipts and expenditures for the year; and by the Trustees upon the financial condition of the Society.

2. General meetings of the Society shall be held on the first and third Wednesdays of every month from November to May inclusive; and at such other times as the Council may determine.

When any meeting provided for by these By-Laws falls upon a legal holiday, said meeting shall be held on the Wednesday following such holiday.

3. At any meeting business not provided for by these By-Laws may be transacted, provided notice of such proposed business has been mailed postpaid at least four days before the meeting to the address furnished by each Corporate Member.

4. Eleven Corporate Members shall form a quorum for business.

5. The order of proceeding at the General Meetings shall be

1. Approving the record of preceding meeting.
2. Business.
3. Scientific communications and their discussion.
4. Adjournment.

SECTION 7. LIBRARY.

1. Members of the Society shall have access to and may take books from the library under the direction of the Library and Publishing Committee, which may by special vote extend the use of the books to others than Members, specifying the conditions under which books may be taken, or may restrict their use even by Members, when, in their opinion, the interests of the Society demand it.

2. The rules and regulations for the use of the library shall be posted in the library room, and a digest of them affixed to each volume.

SECTION 8. MUSEUM.

1. The Executive Committee shall determine the conditions of admission to the museum.

2. Specimens may be removed from the museum only by leave of the Curator who shall take a receipt of the same and be responsible for their return in good order.

SECTION 9. SECTIONS.

1. The Council may authorize the formation of Sections of the Society on the written application of ten Members.

2. Meetings may be held at the pleasure of the Section.

3. The requirements of membership in a Section shall be : —
Membership in the Society.

Written nomination by two Members of the Section at one of its regular meetings.

Election by a three fourths vote of the Members present at a subsequent meeting of the Section.

4. The records of meetings of Sections shall be entered in chronological order upon the book containing the records of the ordinary meetings of the Society.

5. Such report of each meeting as may be judged by the Library and Publishing Committee suitable for publication in the Proceedings or Memoirs of the Society shall be announced by the Secretary at the next regular meeting of the Society.

6. Each Section shall have the right to make additional regulations concerning its organization, subject to the approval of the Council.

SECTION 10. CHANGE OF BY-LAWS.

1. The By-Laws of the Society may be altered or amended by a two thirds vote of the Corporate Members present at any meeting, provided a notice of such intended change shall have been given at a preceding meeting and shall have been mailed postpaid to the address furnished by each Corporate Member, at least four days before final action.

Printed, June, 1899.

No. 2.— *Variation and Sexual Selection in Man.*

BY EDWIN TENNEY BREWSTER, ANDOVER, MASS.

THE proverbial 'inch on a man's nose' suggests the rather obvious fact that certain parts of the human body determine the personal appearance far more than do other parts. These portions, which may be no larger or more useful than others, I shall (for want of a better term) call conspicuous. This paper attempts to show that there is a relation between the conspicuousness of any part of the body, and its variability as measured by the coefficient of variability of its dimensions. (*Cf.* Pearson, '96, p. 265-277; Brewster, '97, p. 269-273. I here follow Professor Pearson in multiplying all coefficients by 100.) The data of the investigation are given in such of the appended tables as are designated by letters, while comparisons and synopses are given in the numbered tables.

I shall first offer evidence to prove that *conspicuous dimensions tend to be more variable than other dimensions*. Table A, the first to be considered, gives the 'coefficient of variability' of ten bone measurements for New England Indians of both sexes. From this it appears that the several dimensions of the head and face have coefficients of variability which may be as low as 2.5 or as high as 5. In other words, some dimensions, when measured by this method, are twice as variable as others. Now it is evident that a person's appearance is determined by the dimensions of the face rather than by those of the head; that it is, as a whole, the face rather than the head, which is noticed and remembered; which is, in short, conspicuous. This, of course, does not mean that every feature of the face is more conspicuous than any feature of the head. The width of the jaw, for example, since it is partly masked by the cheeks, affects the appearance decidedly less than the size and shape of the forehead. But the head, as a whole, is less conspicuous than the face as a whole. If, then, conspicuousness is correlated with variability, the dimensions of the face should be more variable than those of the head, and the mean of the six coefficients of the face dimensions should be greater than the mean of the four coefficients of the head dimensions. A glance at Table A shows that this rela-

tion holds, for the coefficients of the head are obviously smaller than those of the face.

Not only may we say that the face is more conspicuous than the head, but we may go farther and say that the size and shape of the nose affect the appearance more than any other feature of the face. These three propositions should then be true : —

- (1) The nose should be more variable than the head.
- (2) The face without the nose should be more variable than the head.
- (3) The nose should be more variable than the rest of the face.

In the first column of Table 1 is given, for both sexes, the mean of the coefficients of variability of the four head dimensions. Column 4 of the same table gives the mean of the coefficients of the four dimensions of the face, and column 5 the mean of the coefficients of the two nose dimensions. From these figures it appears, that (1) is true for both sexes; that (2) is also true for both sexes; while (3), though true for the females, is not true for males. Under columns 3 and 6 are given the scores for these two tests. Beneath the sign + are given the cases of correlation between conspicuousness and variability; under the sign — the cases in which correlation is wanting. The two tests give a score of 7 to 1 in favor of correlation.

The data of Table A may be made to furnish yet another test of this relation. A moment's consideration will show that we nearly always visualize other persons in full face view rather than in profile, and that we think of other men and races as they look when seen face to face. It follows, then, that transverse diameters of the head and face, which determine the full face aspect, are, in general, more conspicuous than the dorso-ventral dimensions, which are seen more clearly in profile; and that vertical dimensions, which affect both aspects, are more conspicuous than either. Here, again, I do not imply that every transverse dimension affects the appearance more than any dorso-ventral dimension, but only that this statement is true in general. We shall expect to find, then, (1) that the mean coefficient of the three dorso-ventral dimensions is less than the mean of the four transverse dimensions, and (2) less than the mean of the four vertical dimensions, and (3) that the mean of the transverse dimensions is less than the mean of the vertical dimensions. Columns 7, 8, 9 give these means, and show that all three statements are true for women, but only the third is true for men. The

score for this test, recorded as before, is given in column 10, and is 4.2 for both sexes. Column 11 gives the total score for the three tests which have been applied to the data of Table A. Altogether, in eleven cases out of fourteen, conspicuousness is associated with variability.

In Table B are given the coefficients of various skull and face dimensions of Venezuelans, and in Table 2 I have brought together averages corresponding to those of the New England Indians given in Table 1. If the same comparisons are made among these averages as were made among those of Table 1, in every case the more conspicuous dimensions are seen to be the more variable.

The first ten columns of Table 3 repeat, for the data of Table C, the tests already applied to the data of Tables A and B. Column 3 shows seven correct cases out of a possible nine; column 6, twenty-one out of twenty-seven; column 10 shows nineteen out of twenty-seven; a total of 47 out of 63. All the tests thus far applied give a total of 86 to 19, or something more than 80 per cent.

Suppose now, in Table C, I consider the face measurements alone, and divide them into two groups, one of which shall contain the coefficients of all the more conspicuous dimensions, and the other the coefficients of the less conspicuous. Concerning the conspicuousness of some of these dimensions I am unable to form an opinion. But I think I am tolerably safe in claiming that the distance from the ear to the nose root, the distance between the temples (upper face breadth) and the distance between the angles of the jaw (lower face breadth) are less conspicuous than the under jaw length, cheek breadth, and mouth breadth. I may state at this point that I made the division first, and computed the mean afterward. Column 11 gives the mean coefficient of the three less conspicuous dimensions, and column 12 the mean for the more conspicuous. In each of the nine cases the relative magnitude of the coefficient is what would be predicted.

I may go even farther, and compare four conspicuous with four inconspicuous dimensions, by including with the conspicuous dimensions already taken, the distance from ear to chin, and with the inconspicuous dimensions, the distance between the inner angles of the eye (nose root breadth). These two dimensions are not so clearly assignable to their respective classes as the six dimensions first compared. Nevertheless, the distance from ear to chin measures the protrusion of the lower jaw, one of the most conspicuous

features of the lower part of the face; on the other hand, the nose root breadth, though by no means inconspicuous, is, I think, obscured by the more prominent features near it. At any rate, these are the only two face dimensions remaining, which in anywise lend themselves to this classification. Columns 13 and 14, incomplete through lack of data, show in turn complete correlation.

There is, however, one head dimension which is eminently conspicuous, the forehead height. This, in column 16, I have included with the dimensions of column 14; and in column 15, with the dimensions of column 13, I have included the breadth between the ears. I have chosen this last dimension because it is apparently the most variable of the remaining head dimensions, and, in consequence, least favorable to my case. Here, too, in comparing four conspicuous dimensions of the face and one of the head with four inconspicuous dimensions of the face and one of the head, I find in every instance that the more conspicuous dimensions are the more variable.

It seems, at first sight, an easy matter to apply this last test to the data of Tables A, B, and D. But in the case of Table A the number of measurements is too few, and in Tables B and D I have found it impossible to assign the data to the proper groups.

Finally, in column 18, are given the mean coefficients of eight body measurements; these should evidently be less than the coefficients of the more conspicuous face dimensions. So indeed they are, except in the case of the Chinese; and even here, as in every instance, the face including the nose is more variable than the body.

Table D is like A and B, and Table 4 like 1 and 2, and need no comment; they give twelve good cases out of fourteen.

I have now made 142 comparisons between the variability of various dimensions classified according to their importance for personal appearance; and in 120 cases — more than 84% — the more conspicuous dimensions are the more variable. This per cent would doubtless be greater, if the coefficients could, in some cases, have been based on larger numbers of individuals. For in Tables A, B, C, and D, if I throw out five sets of coefficients based on fewer than twenty individuals, I get 89% of favorable cases. Furthermore, in all these comparisons, the number of dimensions is quite as important as the number of individuals; and it is noteworthy that Table B, with 26 dimensions and 129 individuals, gives 100% of good cases. Finally, these comparisons are based on 335 coefficients

computed from 8,551 measurements of 406 individuals belonging to 11 different races. In Table B are four sets of coefficients, corresponding to four groups of individuals of the same race; and it is noticeable how nearly alike are these coefficients for the two sexes, and for individuals from two different localities. This indicates that the coefficient of variability for a particular dimension in a particular race is a rather definite quantity. This datum is taken at random, the choice being determined, for the most part, by the difficulty in finding recorded measurements of both sexes. Every coefficient computed appears in the final result, including even those computed to find how small a number of individuals could be taken before the method would break down so that if it should turn out that variability is not correlated with conspicuousness, the mistaken conclusions of this paper would be due rather to fallacious reasoning than to insufficient evidence or to data improperly selected.

In discussions of variations it has commonly been taken for granted that differences in variability are caused by the greater or less severity of the struggle for existence. But if variability is in any way correlated with conspicuousness, this correlation can hardly be the result of natural selection, since it is difficult to imagine any connection between conspicuousness and utility. Sexual selection will, however, account admirably for this correlation; and the significance of this discussion is this suggestion of the importance of sexual selection in man.

It is not clear just how sexual selection operates to increase variability instead of diminishing it as natural selection is commonly supposed to do. It is possible that sexual selection is pushing men and women in the direction of an aesthetic ideal, and in consequence conspicuous parts of the body cannot settle down to a constant condition. Perhaps variety itself is attractive, so that the individuality which comes from looking unlike one's fellows is an advantage.

To sum up then, I have tried to show that sexual selection has brought it about that parts of the body tend to be more variable in proportion as they are of greater aesthetic value. There is, therefore, this much additional evidence in favor of Darwin's well-known views of the importance of sexual selection in human evolution.

The data here brought together have a certain bearing on some previous studies in variation. Prof. Karl Pearson ('97) has col-

lected a considerable body of evidence which goes to prove that, contrary to the commonly received opinion, men are not more variable than women. In another paper, indeed, Lee and Pearson ('97) have tried to show that among civilized races men are even less variable than women. Neither of these conclusions is borne out by the evidence here presented. In the case of the Pompeians—the only civilized race for which I have the data for both sexes—the men are more variable in 13 dimensions, and the women in 5. Furthermore, the mean of 19 coefficients for the men is 3.60, and for the same number of dimensions for women is 2.68.

As for the equal variability of the two sexes in general, my tables show 60 cases in which the men are more variable and 36 in which they are less variable than the women. Moreover, Table 5, which gives the mean coefficient for each race of Tables A, B, C, and D, shows that in each of the 4 cases in which the coefficients of both sexes are given, the male is the more variable.

Lee and Pearson offer evidence ('97) to show that civilized races are more variable than savage races. This conclusion is contradicted by an equally large body of evidence in the present paper. For it may be seen from Table 5 that the civilized Pompeians are less variable than the other two savage races, the coefficients for which are based on bone measurements; and that of the remaining races, the savage Javanese are more variable than any of the five civilized races except the Magyars. Thus I venture to think that these questions of the relative variability of men and women and of civilized and savage races are still unsettled.

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TABLE 1.
MEAN COEFFICIENTS OF NEW ENGLAND INDIANS (TABLE A).

	1	2	3	4	5	6	7	8	9	10	11
	Mean of 4 dimensions of head.	Mean of 6 dimensions of face and nose.	Head < face and nose. + -	Mean of 4 dimensions of face.	Mean of 2 dimensions of nose.	Head < face < nose. + -	Mean of 3 dorso- ventral dimensions.	Mean of 4 trans- verse di- mensions.	Mean of 3 vertical dimensions.	Dorso- ventral < trans- verse < vertical + -	Total + -
38 ♂	3.45	4.18	1-0	4.30	3.96	2-1	4.21	3.70	3.87	1-2	4-3
25 ♀	2.67	4.12	1-0	4.25	4.30	3-0	3.11	3.90	4.19	3-0	7-0
Totals			2-0			5-1				4-2	11-3

TABLE 2.
MEAN COEFFICIENTS OF VENEZUELAN (TABLE B).

	1	2	3	4	5	6	7	8	9	10	11
	Mean of 9 dimensions of head.	Mean of 17 dimensions of face and nose.	Head < face and nose. + —	Mean of 13 dimensions of face.	Mean of 4 dimensions of nose.	Head < face < nose. + —	Mean of 5 dorso- ventral dimensions.	Mean of 15 trans- verse di- mensions.	Mean of 3 vertical dimensions.	Dorso- ventral < trans- verse < vertical + —	Total. + —
23♂	3.08	5.21	1—0	4.41	8.†	3—0	3.05	4.33	6.00	3—0	7—0
25♀	3.01	5.07	1—0	4.30	7.55	3—0	3.05	3.90	6.67	3—0	7—0
Ipi-Iboto.											
50♂	2.92	4.49	1—0	3.92	6.34	3—0	2.95	3.76	5.25	3—0	7—0
31♀	3.00	4.40	1—0	3.86	6.12	3—0	3.24	3.39	5.91	3—0	7—0
Cerro de Luna.			4—0			12—0				12—0	28—0

TABLE 3 (continued).

10	11	12	13	14	15	16	17	18	19	20
Dorso-ventral-transverse<vertical + —	Mean of distance from ear to nose root, upper face breadth and lower face breadth.	Mean of under jaw length, cheek breadth, mouth breadth.	Mean of 3 dimensions of column 11 and nose root breadth.	Mean of 3 dimensions of column 12 and distance from ear to chin.	Mean of 4 dimensions of column 13 and breadth between ears.	Mean of 4 dimensions of column 14 and forehead height.	H<12 13<14 15<16 + —	Mean of 8 body measurements.*	Body < face. + —	Total. + —
3-0	2.82	5.31	3.00	4.71	4.74	5.25	3-0			9-1
2-1	2.69	5.28	4.43	4.76			2-0			8-1
0-3	2.64	4.87	3.62	4.61	3.23	4.66	3-0			7-3
1-2	2.70	4.35	3.12	4.30	3.49	4.50	3-0			7-3
3-0	3.31	3.67					1-0	3.67	1-0	7-2
2-1	3.70	4.48	4.10		4.06	4.30	1-0	4.48	1-0	8-1
2-1	3.35	4.94		4.45			3-0	4.92†	0-1	8-3
3-0	3.83	4.40					1-0	3.67	1-0	9-0
3-0	4.25	5.20					1-0	3.90	1-0	6-3
19-8							18-0		4-1	69-17

* Brewster, '97, p. 274.

† 5.73 if nose is included with face.

TABLE 4.
MEAN COEFFICIENTS OF POMPEIANS (TABLE D).

	1	2	3	4	5	6	7	8	9	10	11
	Mean of 9 dimensions of head.	Mean of 10 dimensions of face and nose.	Head < face + —	Mean of 8 dimensions of face.	Mean of 2 dimensions of nose.	Head < face < nose.	Mean of 4 dorso-ventral dimensions.	Mean of 9 transverse dimensions.	Mean of 6 vertical dimensions.	Dorso-vent. < transverse < vertical. + —	Total. + —
40 ♂	2.83	4.28	1—0	4.15	4.83	3—0	3.17	3.81	3.73	2—1	6—1
28 ♀	2.78	3.60	1—0	3.93	4.51	3—0	2.58	3.73	3.44	2—1	6—1
Totals			2—0			6—0				4—2	12—2

TABLE 5.

MEANS OF ALL COEFFICIENTS FOR EACH RACE.

	Indians.	Venezuelans.	Pompeians.	Javanese.	Tahitians.	Sudanese.	Roumanians.	Slavs.	Chinese.	Magyars.	Jews.
♂	3.89	4.23	3.60	5.18			4.64	4.70	5.01	5.41	4.95
♀	3.54	4.15	2.68	5.08	3.69	4.03					

TABLE A.
COEFFICIENTS OF VARIABILITY OF CRANIA OF NEW ENGLAND INDIANS. CARR, '80.

SKULL.					FACE.					
	Length.	Breadth.	Height.	Width of frontal.	Basi-nasal line.	Basi-alve-olar line.	Nose length.	Nose breadth.	Orbit width.	Orbit height.
38 ♂	3.53	3.49	3.37	3.41	4.86	4.25	3.52	4.41	3.39	4.72
25 ♀	2.45	3.19	2.51	2.54	2.79	4.10	5.18	3.43	4.42	4.79

TABLE B.
COEFFICIENTS OF VARIABILITY OF CRANIA OF PREHISTORIC VENEZUELAN. MARCANO, '93.
(Pp. 134-137; 150-153; 162-166; 170-175.)

		Max. head length.	Initial ant-post diameter.	Metopic ant-post diameter.	Transverse head diameter.	Breadth between ears.	Lower frontal breadth.	Breadth at stephanion.	Breadth at asterion.	Vertical diameter.
Crania from Ipi-iboto.	23 ♂	2.70	2.79	2.88	2.77	2.69	2.84	3.75	3.41	3.92
	25 ♀	2.00	1.39	1.70	2.26	1.82	2.97	3.33	4.16	7.50
Crania from Cerro de Luna.	50 ♂	2.45	2.83	2.92	2.76	2.39	3.30	3.27	3.44	2.90
	31 ♀	3.20	3.39	3.40	2.58	3.08	3.10	2.83	3.20	3.08
		Exterior biorbital diameter.	Interior biorbital diameter.	Breadth between malars.	Breadth between jugals.	Max. breadth at cheek bones.	Total height of face.	Spino-alveolar height.	Orbit breadth.	Orbit height.
Ipi-iboto.	♂	2.14	2.19	3.89	2.10	2.22	4.44	10.05	4.80	3.38
	♀	3.08	3.35	2.90	2.21	1.97	6.41	10.00	4.77	4.75
Cerro de Luna.	♂	2.41	2.96	3.09	2.85	2.71	3.42	9.43	2.87	4.66
	♀	1.78	2.13	1.83	1.93	3.22	6.33	10.52	3.58	3.11

TABLE B (continued).

		Inter-orbital distance.	Length of palate.	Width of palate.	Distance from ear to eye.	Naso-spinal height.	Max. breadth.	Length of nasal bones.	Breadth of nasal bones.
Ipi-iboto.	♂	10.05	3.27	4.24	3.64	5.43	6.59	8.83	11.40
	♀	4.60	5.21	1.95	4.94	3.07	3.31	8.13	15.70
Cerro de Luna.	♂	6.07	3.03	4.02	3.49	3.33	5.02	7.76	9.26
	♀	5.98	2.73	3.02	3.46	6.05	5.09	6.45	6.91

TABLE C.
LIVING HEADS. WEISBACH, '67 AND '78.

	9 Javanese ♂	8 Javanese ♀	7 Tabi- tians ♀	13 Sudan- ese ♀	26 Rou- manians.	24 North- ern Slavs.	20 Chinese.	20 Magyars.	19 Jews.
Nose length.	7.81	6.02	4.56	5.12	6.33	5.32	8.36	17.00	4.35
Nose height.	14.50	10.40	6.37	6.50	6.01	6.83	10.60	6.25	5.75
Forehead height.	7.44	—	4.85	5.31	6.50	7.21	8.70	8.19	9.41
Upper face height.	4.15	—	2.82	4.37	1.98	5.23	3.22	6.39	6.77
Face height.	6.26	3.64	1.59	2.79	5.06	3.57	4.63	4.52	4.35
Head height.	1.81	6.25	2.50	2.42	—	—	—	—	—
Head length.	3.56	2.40	3.57	3.53	3.02	3.14	2.80	2.93	3.09
Distance from ear to chin.	2.91	3.21	3.85	4.15	—	—	2.98	—	—
Distance from ear to nose root.	3.60	2.16	3.11	1.75	2.96	3.69	3.25	2.30	3.44
Under jaw length.	5.25	7.13	3.16	4.25	3.22	4.59	5.67	4.35	5.39
Head breadth.	3.28	3.16	1.28	2.85	3.38	3.45	2.87	3.22	3.63
Cheek breadth.	2.75	2.83	3.29	2.92	2.54	2.66	4.35	3.36	4.02
Upper face breadth.	1.67	3.29	2.76	3.33	3.54	4.57	3.00	3.92	3.61
Nose root breadth.	7.11	9.65	6.55	4.40	5.76	9.33	6.33	5.01	3.98
Breadth between ears.	8.11	4.81	1.59	4.96	2.76	2.56	3.90	3.40	5.79
Nose breadth.	6.96	3.76	4.42	5.09	4.81	4.46	6.40	5.46	4.47
Mouth breadth.	7.92	5.89	8.16	6.88	4.96	6.19	4.80	5.50	6.19
Lower face breadth.	4.20	2.63	2.06	3.01	3.44	2.88	3.80	5.28	5.71

TABLE D.
COEFFICIENTS OF VARIABILITY OF ANTIQUE POMPEIAN SKULLS. SCHMIDT, '84 (p. 250-251).

	Basion to alveolar border.	Basion to naso-frontal suture.	Basion to bregma.	Opisthion to lambda.	Naso-frontal suture to bregma.	Head length.	Max. head height.	Head breadth.	Max. forehead breadth.	Cheek breadth.
40 ♂	3.61	3.03	2.81	3.37	2.80	2.65	2.57	2.47	2.64	2.95
28 ♀	3.11	3.03	2.44	2.86	2.77	2.33	2.33	3.07	2.70	2.75

	Min. forehead breadth.	Orbit breadth.	Inter-orbital breadth.	Max. breadth of nose opening.	Orbit height.	Nose height.	Upper face height.	Breadth at asterion.	Palate breadth.
40 ♂	3.25	3.12	8.10	4.43	3.33	5.24	5.11	3.35	3.93
28 ♀	2.81	3.78	6.71	4.16	3.73	4.87	4.52	3.74	3.81

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No. 3. — *Notes on the Reptiles and Amphibians of Intervale, New Hampshire.*

BY GLOVER M. ALLEN, INTERVALE, N. H.

THE observations on which this paper is based were made almost entirely during the summer of 1898. Intervale is a small village a few miles to the south of Mount Washington. Its fauna is characteristically Canadian, though with a slight mixture of Transition forms. The country in the vicinity of Intervale offers a variety of conditions. The Saco River with its broad, level meadows or intervalles is near at hand. From the edge of the intervalles the ground rises rapidly, the nearest mountains, Mts. Bartlett and Kearsarge, being but a short distance from the river. The woods are chiefly of white pine, beech, paper birch, yellow birch, black spruce, and aspen. The white pines form a thin belt between the village and the base of Mt. Bartlett. Above them there is a well-marked belt of beeches, extending up the mountain side. Still higher up the birches and aspens (at this elevation, mostly the large-tooth aspen) form a mixed belt, while towards the tops of the mountains the black spruce is the prevailing tree, with here and there a stunted aspen (*Populus tremuloides*). Near the bases of the mountains are numerous small, clear brooks, but larger bodies of water are few. Echo Lake, at the base of Moat Mountain, which is just across the west side of the river valley, is a small sheet of clear water, with a fine, sandy bottom, and so far as I have been able to discover, has no outlet. This and Pudding Pond, a muddy and comparatively shallow pond surrounded by a growth of tall grass and sphagnum, are the principal ponds near Intervale. The summers are warm but short; the winters are cold and protracted.

During the summer of 1898, I collected nineteen species of reptiles and amphibians at Intervale and vicinity, and one of the reptiles proves to be heretofore undescribed. The list is as follows: —

1. *CHRYSEMYS PICTA* (Herm.). Painted Tortoise.

This tortoise is found rather commonly in both Echo Lake and Pudding Pond, and is frequently seen on bright days, sunning on

projecting rocks or logs in the water. At such times it is shy and will slip off and disappear in the mud, while the intruder is yet a considerable distance away. It is amusing to watch it in its endeavors to scramble upon a floating board. It experiences but little difficulty in getting its fore feet upon the board, but there the struggle begins. Raising itself to the height of its fore limbs, with its neck stretched out forward as far as possible, it makes frantic endeavors to get its hind feet upon the plank. After falling back into the water several times, it finally succeeds in gaining a hold with its hind claws, and so pushes itself forward upon the plank. In all the specimens I have examined from Intervale, the dorsal plates are arranged in transverse rows of threes as in typical specimens, but it is of interest to note that in a few specimens from eastern Massachusetts, I have seen these scales alternating as in the western species, *C. marginata*, though in other respects these specimens were typical of *C. picta*. In a specimen taken at Intervale, late in August, 1898, the plates were in process of peeling off. Most of them had one or two corners loose and came off easily, when given a slight pull.

2. *THAMNOPHIS SAURITA* (Linn.). Ribbon Snake.

On the Intervale by the river, I saw what I am very positive was a specimen of this snake, but it was so agile that it succeeded in making its escape through the long grass.

3. *THAMNOPHIS SIRTALIS PALLIDULA* subsp. nov. Northern Garter Snake.

Type locality. Intervale, New Hampshire.

Geographic distribution. From the White Mts. of N. H. and the Adirondacks of N. Y. northward into New Brunswick and Nova Scotia, and possibly farther.

General characters. Ground color above, olive to olive-brown; dorsal stripe, except at its inception, almost obsolete; the interlinear spots of reddish scales with narrow black edgings and black interspaces. Belly, in young specimens grayish white, in adults from grayish white to light yellowish.

Description. Body rather slender, head wider than neck. Frontal large and roughly hexagonal. Two nasals, the nostril between. One loreal. Usually three small post-orbitals and one large ante-orbital. Supra-labials seven; the fifth and sixth largest. Infra-labials ten; the fifth and sixth largest. Dorsal scales carinated and arranged in nineteen rows. Anal plate entire. Gastro-

steges (from eleven specimens), 143-152. Urosteges, 117-143. Total length, 662 mm.; tail, 141 mm.

Color (from living specimens). Adult; ground color above, brownish olive to olive-brown. Dorsal side of the head, olive, with two small yellowish spots at the inner margins of the parietals. Superior labials, light greenish white to yellowish. The dorsal stripe, which begins at or slightly behind the posterior margins of the parietals, is easily traceable for an inch or two as a light yellow marking, occupying one, and two half rows of scales. From here it may usually be traced back as far as the tail as an indistinct grayish olive marking which, on close inspection, it is difficult to separate with certainty from the surrounding olive-colored area. The lateral stripes (one on each side) occupy the second and third scale rows. In color they are from greenish yellow to ochraceous, brightest anteriorly, and sometimes tinted with chestnut. Between the dorsal and lateral stripes, there are, on each side, two longitudinal series of squarish spots, best seen when the skin is distended. The spots of the upper series alternate with those of the lower series. Each spot involves from three to four scales of two transverse rows, and each scale of the spot is chestnut colored, with narrow black edgings and black interspaces. The two rows of spots are usually separated by a single longitudinal row of olive scales, which form the sixth row in transverse series. Interspaces of other scales above the lateral stripe are white. Below the lateral stripe, the first row of scales and the ends of the gastrosteges are usually light chestnut and sometimes olive-green, as in younger examples. Beneath, from pearly white to light greenish yellow. A row of black spots is present on the ends of the gastrosteges. The black of each spot may extend upward along the anterior margin of the gastrostege and beyond so as to include the anterior margin of the next scale or two in the rows above, but such markings do not occur very regularly.

Young. Similar to adult in general coloration, but the ground color is a very pale olive, the dorsal stripe is grayish white and rather more distinct than in the adult. The lateral stripes are very pale yellow, sometimes hardly distinguishable from the color of the belly, which is grayish white. A large fuscous nuchal spot on each side.

In his original description of *Coluber stralis*, Linnaeus gives (Syst. nat., ed. 10, 1758, p. 222) the characters as "three greenish

blue stripes; narrowly striped with fuscous. *Gastrosteges* 150, *urosteges* 114." He received his specimens from Kalm and gives the type locality as "Canada." Kalm did his collecting in northern Vermont, along Lake Champlain, and from Montreal to Quebec. He apparently makes no mention of this snake, in his journals covering this region, so that it is impossible to say whether or no he got his specimens from northern Vermont, bordering southern Canada, or from Quebec, if indeed he got them from that region at all, though Kalm was a careful collector and would probably have labeled his specimens correctly. The description of Linnaeus was doubtless taken from alcoholic specimens in which the three yellow stripes had been turned by the alcohol to a "greenish blue." The fact of there being *three greenish blue stripes* would seem to point to the probability that he was dealing with the more southern form, with the three bright yellow stripes, since specimens of *T. s. pallidula*, even in life, have the dorsal stripe almost obscured, and specimens preserved in alcohol or formalin soon lose the color of the stripes to such an extent that in many cases the stripes would be overlooked altogether, unless known to have been there originally. Furthermore, most of the country through which Kalm passed, was of the Transition and not the Canadian zone, of which *pallidula* is the characteristic form. The evidence, thus, as to which of the two types, the northern or the southern, Linnaeus possessed, is about equal on both sides, though perhaps slightly in favor of his specimens having been of the southern form. I shall, therefore, restrict the name *Thamnophis sirtalis* (Linn.) to the brighter-colored form found in the Transition and Austral zones of the East, a description of which from several live specimens from Cambridge, Mass., is as follows:—Size, proportions, and scales as in *T. s. pallidula*. Color: (young and adults) above, black, with three greenish yellow, longitudinal stripes; one median dorsal, two lateral. The dorsal stripe occupies one and two half scale rows, the lateral stripes occupy the second and third rows. Two longitudinal series of squarish spots on each side between the dorsal and lateral stripes, the spots of the superior row alternating with those of the inferior. These spots are very often entirely black and can then best be seen by pulling apart the scales, when the spots are outlined by the black spaces between the scales composing the spot. Occasionally one or two of the scales will have a faint reddish portion in the middle, thus approaching the condition in *pallidula*.

The first row of scales is blackish olive to dark olive, this color extending over the ends of the gastrosteges. A more or less perfect row of gastrostegal spots is present, and, as in *pallidula*, the spot is frequently continuous with a black border which runs along the anterior margin of the end of the scute, and extends up between the scales of the first, or first and second rows. Specimens are occasionally found which are of a browner shade than those just described. In these there is a tendency to more or less redness in the spots, and the spots are plainer. Some very young specimens are lighter than described above, though generally there is but little difference in color between old and young.

Thamnophis sirtalis pallidula needs comparison with no other of the *sirtalis* group except *T. sirtalis* proper, from which it differs in the obscurity of the dorsal stripe, which is grayish, not yellow; the ground color, which is olive-brown, not black or blackish; in the chestnut color below the lateral stripe, where *sirtalis* is olive; in the lighter color of the belly, especially in the younger examples; and in the interlinear spots as previously described. The young of *pallidula* are even paler than adults and are easily distinguished from those of *sirtalis* proper by the gray belly and dorsal stripe, pale olive ground color above, and the pale lateral stripes, as well as by the interlinear spots.

The Northern Garter snake is abundant at Intervale, where I captured a large number. I have also taken it at Caribou, northern Maine, and Mr. W. A. Hickman informs me that he has taken it at Pictou, Nova Scotia. It is apparently characteristic of the eastern Canadian zone and is usually found in or near woods. At a short distance, the general coloring of the dorsal surface resembles the color of the pine needles and dead beech leaves of its forest home. This snake feeds largely on wood frogs (*Rana sylvatica*) and toads (*Bufo americanus*), which abound in the damp woods. On several occasions, after having captured these snakes, I have known them to disgorge frogs which had recently been swallowed.

4. *NATRIX FASCIATA SIPEDON* (Linn.). Water Snake.

This species I found only in the bog of rank grass and sphagnum around Pudding Pond. I caught one large specimen in a "Cyclone" mouse trap set in a *Microtus* runway. The snake had evidently been following the runway, and in attempting to pass through the trap, had sprung it. It had died, apparently without

a struggle, as the strong springs of the trap had come down violently just back of the skull.

5. *STORERIA OCCIPITOMACULATA* (Storer). Red-bellied Snake.

Apparently this little snake was not common, though I saw several specimens. One was seen basking in the sun on a dry board in Pudding Pond bog, but as I approached, it quickly slipped away among the grass. Occasionally it is found dead in the road, having been run over by passing vehicles as it was sunning itself. Dr. A. S. Packard presented me with a specimen found, thus killed, at Intervale. Its colors were unusually bright. The back was a blue-black instead of the usual olive-brown, and the belly a bright red, almost scarlet.

6. *LIOPELTIS VERNALIS* (DeKay). Grass Snake.

Of this species I took several specimens, and these always in grassy places. It seems to be well distributed and rather common. One was found dead in a grassy spot in the woods. Others were taken at the Pudding Pond bog and on the edge of the intervalles. At Pudding Pond, I took one from under a board and brought it home, where I placed it in a glass bottle, some three inches in diameter. On looking at it the next morning, I found it had nearly completed casting its skin, and only a couple of inches of its tail still remained to be withdrawn. In the Pudding Pond swamp I also found a cast skin, evidently of this species, in a small bush, a couple of feet from the ground. It was twisted in and out among the twigs, showing that it had been cast as the snake was climbing about. I have always found this snake very gentle, and have never had one offer to bite me. Usually, it seems to avoid the bright light, and is often found under stones or boards. Two, which I kept in captivity for over a month, hid, most of the time, under a bunch of grass in their box.

7. *CROTALUS HORRIDUS* Linn. Banded Rattlesnake.

Although I myself have not met with this species at Intervale, one or two are reported every summer from the vicinity. Several have been seen or killed on Rattlesnake Ledge, a large rocky mass on the southern slope of Mt. Bartlett. An old inhabitant tells me that rattlesnakes were formerly common on the mountains east and south of Intervale. One of the White Mountain guides, who has spent most of his life among the mountains, tells me, however, that he has never met with a rattlesnake. A specimen killed on Mt. Bartlett a couple of years ago was examined by Dr. Packard, who

tells me that it was much darker than specimens from farther south. I have examined a couple of rattlers' skins from the Adirondacks, and found them to be more uniformly dark than specimens from Massachusetts, the white of the latter giving place to a dark yellow-brown. It thus seems quite probable that the northern rattlesnake is distinct.

8. *RANA PALUSTRIS* Leconte. Marsh Frog.

On the broad meadows of the Saco Valley, this frog is common along the little ponds and brooks. In Echo Lake, I found a single young specimen in July, which still retained its tail, but otherwise I was unable to find this species in the lake, *Rana catesbiana* being the common frog there. During the summer, the Marsh Frog may frequently be found hopping about in the grass at a considerable distance from the nearest body of water. On the 10th of September, 1897, I came upon a single specimen halfway up Mt. Bartlett, and at a long distance from the nearest water. The small mountain brooks for half or three quarters of a mile around were dried up, as was also a small swamp near by. This swamp, of a few square rods in extent and overgrown with bushes and sphagnum, is filled with water during early summer, but dries up later in the season. It is probable that this frog had been living in the marsh, and when it dried up, was forced to seek new quarters. Other than in this instance, I have not found the species in the woods. *Rana virescens* I did not find, though I looked for it carefully. It probably occurs in the region.

9. *RANA CLAMITANS* Latr. Green Frog.

Next to *R. sylvatica*, this is probably the most abundant frog. It occurs among the small ponds and brooks on the intervalles, but avoids the swifter waters of the river. It works its way up along the small brooks which flow down into the river valley from the surrounding mountains, and is not uncommonly found, along these brooks, for some distance into the woods. Such specimens, living in the cold clear brooks, usually average brighter in color than those found in the open muddy ponds on the intervalles. In the summer it is not rare to find single specimens at a considerable distance from the nearest water. I even found one hopping along the sidewalk, one evening in August, at about one hundred and fifty yards from the brook at the edge of the intervalles. This brook flows along the base of a steep bank which the frog must have climbed in the course of his wanderings. The following

observations made on frogs of this species at Newton, Mass., are of interest psychologically.

Several frogs living in a certain small muddy pond in a wood were persecuted by boys throwing stones at them. This made the frogs very shy, so that when anyone approached, they would quickly disappear among the dead leaves at the bottom. After having frightened them in this way, I have sometimes sat down and waited for ten minutes or so, till they again appeared, breaking the surface of the water without a ripple, and sitting motionless as before. After they had remained thus for a few minutes, I threw small pebbles into the water near them, but they paid no attention whatever. Finally I threw good-sized stones at them, which splashed the water over them and even made them rock on the small waves, but even then, they would often remain where they were, apparently suspecting no danger. As soon, however, as I arose and walked near them they saw me and retreated beneath the surface. I have seen painted tortoises (*Chrysemys picta*) show the same indifference to stones falling near them, provided they saw no movements to indicate danger. It would thus seem, that these animals have learned to associate danger with the approach of man, but after they have assured themselves that the coast is clear they will not easily take fright unless they are warned of danger by seeing some suspicious movement.

These frogs do not seem to feed much during the day, but at such times sit basking in the sun. Towards evening they become active, and may be heard every now and then splashing in the water as they plunge after some passing insect.

10. *RANA CATESBIANA* Shaw. Bull Frog.

Rather common in the small ponds on the intervalles, whence its loud notes may be heard well into July. In Echo Lake, this frog is very common, and great numbers of young ones were found there during July. These were in various stages of development, most of them having acquired all four legs, but still retaining the greater part of the tail. On one bright sunny day in July, I found a great many under pieces of wood lying in the water near shore, and saw others swimming along the edge of the lake. This frog, with the exception of a very few *R. palustris*, seems to be the only frog in the lake.

I caught one large specimen from a small muddy pond, and, taking it home, kept it for a while in clear water in a large white

jar. When captured, the frog was a dark muddy brown, but before long it cast off the outer layer of epidermis, leaving a clear green skin with a few dark olive blotches. This change of color on putting it into clear water is suggestive of the cause for the difference in color between specimens of *R. clamitans* living in the clear mountain brooks and those living in the muddy ponds and streams of the river valley.

11. *RANA SYLVATICA* Leconte. Wood Frog.

This is an abundant species in the cool, damp woods, and it works its way well up the mountains. I caught one in a "Cyclone" mouse trap in a dried-up bog near the top of Mt. Bartlett, at an altitude of about 2,500 feet. This little bog was surrounded by ledges, from which grew stunted spruces and balsams. This frog is commonest in the beech woods and so closely resembles in color the dead beech leaves that not infrequently, even after having seen one jump, it is with difficulty distinguished from the background. When frightened, it takes prodigious leaps in an erratic course, and usually escapes into some hole or under a log. At night, while walking in a damp spot in the woods, I found numbers of them congregated in the path, where they had probably come to feed. As I passed along, they jumped aside into the bushes. Rarely have I heard them utter a sound in the summer, though occasionally, when in the woods at night, I have detected their faint rasping "crau-au-ák."

12. *BUFO AMERICANUS* Leconte. Common Toad.

This is an abundant species from the river well up the mountains. During the summer, very many small ones, ranging in size from one half an inch to an inch and a half, are to be found in the woods. The frantic struggles of these little ones as they scramble over the leaves and twigs are very comical. Frequently they make no progress at all, and struggle blindly to get up an almost perpendicular slope, with a dogged persistence, which, however, sometimes accomplishes its purpose. Toads are abundant on the grassy intervalles, and after dark many appear in the roads made for hay-ing carts. Apparently they are in search of insects, and are also attracted by the warmth of the dusty roads which have all day been exposed to the sun.

After the breeding season, the toad's song changes from a shrill, prolonged pipe to a shorter, lower-toned note, that, at night, has a peculiar weirdness, and almost reaches a wail. This note is heard

mostly at evening and during the night, though I have occasionally heard it early in the morning and in the late afternoon.

13. *HYLA PICKERINGII* (Storer). Pickering's Hyla.

This delicate little frog is very abundant in the woods and groves, especially in the damp, deciduous woods of beech, birch, and aspen, along the bases of the mountains. It seems to live mostly well up in the trees, whence its shrill cries are often heard. After July, it seems to get more noisy in the woods, and may be heard at almost all hours of the day. These frogs appear inactive during the night, though I have heard their notes in early September until about 7.30 P. M.

They are hard to find, as they will frequently, after uttering a few notes, stop piping and remain silent for long intervals. They are occasionally found hopping about in the woods, and at such times can be captured with little difficulty, though they are almost as nimble as wood frogs. Apparently they can change their color only to a limited extent, by making the X-mark on the back and the other darker markings change from a rich yellow-brown to a gray so pale as to be almost indistinguishable from the ground color of the back. When jumping from one leaf to another, or to any vertical surface, they will always come to rest with the head pointing up. When placed in a bottle, and then turned so as to be upside down, they will always turn around until the vertical position, with the head up, is reached.

14. *HYLA VERSICOLOR* Leconte. Tree Toad.

Abundant in groves, orchards, and shade trees from the river valley into the woods, though apparently commonest in the more open areas between the river and the woods. During June and early July, it is heard tooting from the trees on every side, during the warm evenings. As the summer advances it is less often heard, and during August and September only an occasional note is sounded. It sings mostly during the evening and night, though after a shower during the day, its notes may be heard. I have also occasionally heard it in the woods at noon, on hot sunny days.

I once found one on the intervalle, squatting on a large, dark colored rock, under an oak. It looked very much like a thick piece of lichen and had turned a grayish white color. It was clinging to the rock with head lowered, and feet tucked in close to the body, so that at first I was completely deceived, and only on attempting to remove the lichen, did I discover it.

15. *DIEMYCTYLUS VIRIDESCENS* Raf. Common Newt.

Apparently this species was uncommon. From Echo Lake, I took a single specimen in the larval condition, about the last of July. Another, an adult, was found dead in a small pool on the intervale, but other than these I found no specimens of this form. Of the land form, "*miniatus*," I found, late in September, a single specimen, lazily swimming in shallow water near the shore of Echo Lake. It was so listless in its movements that I easily captured it in my hands.

16. *DESMOGNATHUS FUSCA* Raf. Dusky Salamander.

The commonest salamander. I found it in numbers under old logs, stones, or leaves near the small mountain brooks, but in no case were adults found in the streams. What I took to be the larvae of this species, though I did not rear them through, were common in all the pebbly mountain brooks, especially in places where there was a bottom of granite sand and pebbles. Not infrequently I found the adults at a considerable distance from any brook, but in such cases they were always under old logs in cool, damp places. When uncovered they could easily be captured, as they seemed dazed by the sudden light. They seem to be most active at night. I once caught three and put them in a small bottle with a perforated cork in its mouth. During the day, they remained contentedly in the bottle, occasionally moving about or trying to assume an erect position on the side of the bottle. During the night, however, the two smaller ones managed to crawl through the hole in the cork, and were found next morning covered with dust, on the floor. The third could not have gone through the hole by reason of its larger size, otherwise it would doubtless have followed the others.

None of the Intervale specimens had any perceptible membranous expansion on the tail, and were, for the time, terrestrial. I therefore carefully compared them with Cope's original description of *Desmognathus ochrophaea* (Proc. acad. nat. sci. Phil., 1859, p. 124), which is as follows:—"Color above, varying from bright, to dirty and fuscous straw-color, most specimens with an indefinite medial row of irregular brown spots; a deep brown line passing through the eye and along the dorso-lateral region of the body to the end of the tail; distinctly defined along its upper edge, fading into fuscous marblings on the sides. Belly pure white. Susquehanna Co., Penn. A terrestrial species."

In Bulletin 34, U. S. nat. mus., 1889, he gives a more extended description, and mentions the light line from eye to rictus, and gives the costal grooves as thirteen, not counting the one immediately in front of the groin. The mandibular teeth of the males, he says, are longer than in *fusca*. Through the kindness of Mr. S. Garman, I have been enabled to examine the specimens of *Desmognathus* in the collection of the Museum of comparative zoology, which, together with the series in my collection, makes a total of about 90 specimens from various points from Rangeley, Maine, to Georgia. The Intervale specimens agree well with Cope's description in most cases, but the entire series shows that there is a considerable variation in the amount and extent of dark mottling underneath and on the sides, and that there is no constant color difference between *fusca* and *ochrophaea*. In the small series from Rangeley, Maine, one specimen, a very old individual, is almost black all over, but has the belly somewhat mottled with white, and is provided with a membranous caudal expansion. In the same lot are other specimens agreeing perfectly with the description of *ochrophaea*. The specimens from North Carolina are dark, with the membrane, and a specimen from Georgia is light on the belly, but its tail has been lost. A series of breeding specimens from Plainfield, N. J., are colored as in *ochrophaea* and have the tail expansion. The series from Intervale shows variation from light bellies to heavily mottled, but all lack the caudal expansion. In short, an examination of the entire series shows that the color variation is entirely individual and seems to have no geographic bearing; that the color differences as well as the character of length of teeth have no weight; and that the only difference between the two species is the presence or absence of a caudal expansion. This character can hardly be looked upon as having much weight. Specimens which can easily get out upon land after the breeding season, would doubtless, if they remained away from the brook, suffer a reduction of the membrane, just as the webs in certain of the *Anura* are reduced after the breeding season is over. Others, which from necessity or choice remain in the water, would retain the membrane in consequence. Specimens of *ochrophaea* taken in the breeding season would doubtless show the membranous expansion, and, indeed, the series from Plainfield, N. J., which has the light bellies and coloring as Cope describes, shows also the fin-like membrane on the tail. I can not find that there is a single good character for *ochrophaea*.

17. *SPELERPES BILINEATUS* (Green). Two-lined Salamander.

This slender little salamander is rather common under pieces of wood by the wet banks of little forest brooks, in much the same localities that *Desmognathus fusca* inhabits. It is agile, and when once aroused, scrambles about with great rapidity. I found one in the crannies of a big log, lying across a small brook. On trying to capture it, it scrambled off the log, and, plunging into the water, swam quickly to the bottom and hid beneath a leaf. Like other salamanders, it will walk off the edge of a high box or table with the utmost unconcern, and strike the floor without suffering any apparent inconvenience.

18. *PLETHODON ERYTHRONOTUS* (Green). Red-backed Salamander.

This is a common species under old logs in the damp beech woods, where there are one or two under almost every old log. These logs are, in most cases, sunken slightly into the ground, so that there would seem to be no means of egress at the sides, but there is usually a small hole or two leading from underneath the log down into the ground, and into these holes I have seen the salamanders go when pursued. Whether they make these holes or not, I do not know, but they evidently use them to get in and out under the logs.

The series taken at Intervale shows a considerable range in color variation. Some specimens are coal black on the sides, with a bright red stripe, and others are only lightly mottled on the sides with white and dusky, the dorsal being rather dull. In this species and the two preceding, it will generally be found that the part of the dorsal stripe just at the base of the tail is the brightest and most free from darker spots, and remains distinct longest when the animals darken with age, as in the case of *Desmognathus fusca*.

19. *AMBLYSTOMA PUNCTATUM* (Linn.). Yellow-spotted Salamander.

After a rain, I obtained a single specimen of this species from under an old decaying log in the beech woods. Further search failed to reveal others.

Note. Since writing the above a fine specimen of *Thamnophis saurita* has been taken on the intervalles.

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No. 4. — *Studies in Diptera Cyclorhapha*. 1. *The Pipunculidae of the United States*.

BY GARRY DE N. HOUGH, NEW BEDFORD, MASS.

This is a small family of mostly small flies, from three to five millimeters in length. A better idea of their appearance can be obtained from the figures on p. 473 of Professor Comstock's Manual for the study of insects than by any description that can be written.

The family contains but four genera which may be thus distinguished:—

1. Occiput scooped out, closely applied to the convex cephalic surface of the thorax. Body, long, hairy 2
 Occiput not scooped out, not so applied to the thorax. Body naked or very slightly hairy 3
2. Discal cell present PROTHECUS Rond.
 Discal cell absent CHALARUS Walk.
3. Abdomen elongate, thorax with well-developed bristles
 NEPHROCERUS Zett.
 Abdomen not particularly elongate, thorax without well-developed bristles PIPUNCULUS Latr.

For an elaborate characterization of these genera see Becker's monograph of the European species, Berl. ent. zeits., 1897, vol. 42, p. 25-100.

Of the four genera of this family all except *Nephrocerus* are now known to occur in this country.

CHALARUS. In my collection are two specimens, apparently of different species. One was collected here by myself, the other in Colorado by C. F. Baker. Neither is in sufficiently good condition to use as the basis of a description.

PROTHECUS. *Pipunculus lateralis* Walk. (Dipt. Saund., p. 216) is referred to *Prothecus* by Mr. Coquillett (Proc. acad. nat. sci. Phil., 1895, p. 331). *Pipunculus opacus* Will. (Trans. Amer. ent. soc., 1886, vol. 13, p. 295) also belongs here. The femora of *P. lateralis* are "serrated beneath for half their length with very small black teeth"; the femora of *P. opacus* are not so serrated.

PIPUNCULUS. By the kindness of Mr. Samuel Henshaw I have

recently been permitted to examine the types of Loew's species and thus to make sure of the correctness of the determinations of the species in my collection. As far as I am aware, none of the species described and tabulated by Professor Williston in *Biologia Centrali-Americana*, vol. 3, have yet been found in the United States. It is not unlikely that some of them will be found in our most southern states. I strongly suspect that *P. reipublicue* Walk. is the same as *P. fuscus* Lw. and that *P. translatus* Walk. is *P. subvirescens* Lw. Professor Williston's description of *P. aridus* (Dipt. of Death Valley expedition, p. 255-256) applies exactly to *P. subvirescens* Lw., with which it is therefore probably synonymous. I shall arrange the species in accordance with the tables in Becker's monograph.

Division 1. Stigma wholly or partly colored; abdomen wholly opaque; third antennal joint usually long acuminate.

Division 2. Stigma wholly or partly colored; abdomen wholly or partly shining; third antennal joint usually obtuse.

Division 3. Stigma not colored at all.

Division 1.

1. Fourth longitudinal vein without an appendix.
2. Legs not wholly black, at least the knees yellow.
3. Abdomen naked, at most with a few scattered, erect, fine hairs.
5. Hypopygium (sixth abdominal segment) of varying size but not larger than two abdominal segments together.

7. Stigma (subcostal cell) not colored its whole length.

8. Males	9
Females	10

9. Fourth longitudinal vein with a very distinct angle at its junction with the hind cross vein.

- a. Hypopygium without a cleft.

Third antennal joint obtuse *fasciatus* Lw.

Third antennal joint prolonged into a long white process *subopacus* Lw.

- b. Hypopygium with a cleft.

Hypopygium small, shiny, only thinly pollinose; cleft to the right of the median line *nigripes* Lw.

Hypopygium large, opaque, thickly gray pollinose except a spot near the cephalic border; cleft to left of median line *atlanticus* sp. nov.

P. fasciatus Lw. In the Loew collection there is a single male.

Opaque, black; halteres and antennae black; third antennal joint short and obtuse. Dorsum of thorax opaque with brownish gray pollen. Base of each abdominal segment black and opaque; the remainder of the first segment densely white pollinose; remainder of the other segments with grayish pollen which becomes whiter, thinner, and less opaque toward the sides. Sixth segment of moderate size, black. Legs black; apices of femora and bases of tibiae yellow or reddish yellow. Wings gray, toward base more purely hyaline; stigma brown; veins black; small cross vein near the junction of the basal and middle thirds of the discal cell; third segment of costa shorter than the fourth.

P. subopacus Lw. In the Loew collection a single female. Brownish black. Halteres yellow. Antennae black; third joint prolonged into a long white process. Dorsum of thorax lightly sprinkled with brownish gray pollen. Abdomen brown black almost shining; first segment except the cephalic margin, other segments toward the sides and caudolateral angles whitish pollinose. Sixth segment of male small and without cleft. Femora black, thickly gray pollinose, except mesal surface of posterior femora, which is shining black. Apex of femur sometimes yellowish. Tibiae vary from yellowish with a black ring to black (somewhat gray pollinose) with yellowish base. The tarsi are black or brown with more or less yellow on the first one or two joints. Wings grayish hyaline; stigma brown; veins black; small cross vein at about the junction of the basal and middle thirds of the discal cell; third segment of costa about equal to the fourth.

P. nigripes Lw. In the Loew collection there is a single male without a head. Brownish black. Antennae black; third joint short acuminate. Dorsum of thorax and scutellum brown pollinose, subopaque. Abdomen wholly opaque. First segment, except at base, white pollinose. Second, third, and fourth segments velvety black, each with a caudal, transverse, dark gray pollinose fascia. Fifth segment brown pollinose, subshining, whitish pollinose on the sides. Sixth segment black, rather shiny, thinly gray pollinose; its cleft considerably to the right of the median line. Legs black. Femora grayish pollinose to a varying extent except the mesal surface of the posterior femora, which is shining black; the extreme tips of the femora are yellow. Flexor surface of anterior and middle femora with rows of tiny black spines. Tibiae yellow at base to a varying extent. First one or two joints of the

tarsi yellow or brownish yellow to a varying extent. Wings grayish; stigma brown; veins black; small cross vein at a point apicad the junction of the basal and middle thirds of the discal cell, but before the middle of that cell; third costal segment about twice as long as the fourth. Halteres black except base of peduncles yellowish.

P. atlanticus sp. nov. Two males and three females. New Bedford, Mass., Hough; Montgomery Co., Pa., C. W. Johnson. Length 3 mm., length of wing 5 mm. Brown black, mostly gray pollinose, with wholly yellow legs and very distinctly banded abdomen. Antennae brown with very fine whitish pubescence, third joint short, oval, obtuse. Dorsum of thorax and scutellum black brown pollinose, toward the sides and on the humeri more grayish. Pleurae, metanotum, and coxae gray pollinose. Legs wholly yellow, appearing more or less silvery gray pollinose according to the incidence of the light, except the tips of the tarsi, which are black. The four anterior femora on the flexor surfaces and all the tibiae have rows of extremely minute black spines. Abdomen wholly opaque. First segment wholly gray pollinose except a narrow black cephalic border. Second segment wholly gray pollinose, the pollen thinner on the middle of the segment, so that in some specimens there seems to be a faint median, transverse, black brown fascia. Third, fourth, and fifth segments wholly gray pollinose, except a cephalic, transverse, blackish brown fascia which gradually fades out toward the sides and a median, caudal, blackish brown spot which is connected with the cephalic fascia. On the dorsum of the abdomen the relative widths (measured cephalo-caudad) of the blackish brown fascia and the gray pollinose portion vary in different specimens, sometimes the one and sometimes the other being the wider; the sides of the segments are, however, wholly gray pollinose. The sixth segment is wholly gray pollinose except a small brownish black spot cephalad; this segment is rather large and is divided into three very unequal portions by two dorso-ventral clefts, both of which are to the left of the median line. The one nearest the median line is about halfway to the lateral border, while the one furthest laterad cuts off not over one sixth of the segment. Remainder of genital apparatus yellow. Halteres with yellowish brown peduncle and black knobs. Wings grayish hyaline, veins black; small cross vein at about the junction of the basal and middle thirds of the discal cell; third costal segment about equal to the fourth.

10. Ovipositor straight.
11. Sixth abdominal segment not furrowed.
 - a. The lanceolate terminal piece of the ovipositor not longer than the fifth abdominal segment
atlanticus sp. nov.
 - b. The awl-shaped terminal piece of the ovipositor as long as the second, third, fourth, and fifth abdominal segments together *subopacus* Lw.

These females are like the males except for the sexual differences. As far as I know, the females of *P. fuscatus* and *P. nigripes* are unknown.

Division 2.

- Dorsum of thorax with delicate but distinct hairs 1
1. Abdomen shining black or bronze with opaque black fasciae or spots on the cephalic borders of the segments; males 2
Abdomen shining black without opaque black fasciae but with gray side spots; mostly females 8
 2. Fourth longitudinal vein not interrupted 3
 3. Dorsum of thorax pollinose on the cephalic half without any clearly defined boundary line between the pollinose portion and the shining caudal portion 4
 4. Abdomen with gray side spots 5
 5. Abdominal segments with moderately broad opaque black fasciae at their cephalic borders.
 - a. Tibiae largely brownish black *cingulatus* Lw.
 - b. Tibiae yellow with scarcely a suggestion of brown; hind tibiae rather strongly curved *fuscus* Lw.
 8. Dorsum of thorax more or less pollinose 11
 11. Tibiae between a brown and a yellow, seeming now one, now the other, according to the incidence of the light. Awl-shaped terminal piece of ovipositor straight *nitidiventris* Lw.

P. fuscus and *P. nitidiventris* belong to the difficult group of *P. ater* Meig. It is not unlikely that they will prove to be the two sexes of one species.

P. cingulatus Lw. In the Loew collection a single male. "Grayish black. Antennae wholly black; third joint short, rather obtuse. Dorsum of thorax opaque with brownish cinereous pollen; pleurae sprinkled with whitish cinereous pollen. Scutellum black, moderately shining. Metanotum white pollinose. First abdominal segment white pollinose with a median black spot; the rest of

the abdomen black, shining, with white pollinose sides, each segment with a slender, basal, dark cinereous pollinose fascia. Femora black except the yellowish apices," hind femora shining black on mesal surface, the others not at all shining; "tibiae brown black, basal third of all and apex of the anterior ones reddish testaceous; tarsi reddish testaceous, towards the apex brown, last joint black or black brown. Wings slightly brownish cinereous, stigma brown."

P. fuscus Lw. In the Loew collection three males. Black brown. Antennae black, third joint short, rather obtuse. Dorsum of thorax brown pollinose, opaque, towards the caudal margin subshining. Scutellum black, shining. Metanotum and first abdominal segment, except its base which is black, cinereous pollinose; second, third, fourth, and fifth segments velvety black on their cephalic halves and metallic, shining bronze-colored on their caudal halves (a favorable incidence of light is necessary clearly to make out the extent of the velvety black portion); the black of the second segment is to a certain extent cinereous pollinose, and each segment has on the sides an indistinct grayish pollinose spot; the fifth segment is much longer than the preceding ones; the sixth is much larger still, not symmetrical, and wholly shining bronzy except for a widely interrupted transverse fascia on its cephalic border. Tibiae yellow with scarcely a suggestion of brown; hind tibiae rather strongly curved. Femora black except base and apex which are yellow; lightly white pollinose except the mesal surface of the hind ones, which is shining black; all of them with a certain amount of white pile, the pile on the posterior surface of the middle femora much longer and denser than elsewhere; flexor surfaces of all with rows of very minute black spines. Wings cinereous; stigma brown; small cross vein at junction of basal and middle thirds of discal cell; veins black; third costal segment longer than the fourth. The relative lengths of the third and fourth costal segments in this and the following species are very difficult to determine on account of the extremely acute angle at which the first vein meets the costa, the brown color of the stigma, and the rather large size of the veins, so that the exact point of junction of the first vein and costa is hard to see.

P. nitidiventris Lw. In the Loew collection a single female. Blackish cinereous. Antennae black brown, third joint with the apex short acuminate. Dorsum of thorax opaque with whitish cine-

reous pollen, in the middle brownish cinereous. Scutellum black, moderately shining. Metanotum whitish pollinose. Abdomen wholly black and shining; first segment except at base white pilose; second very slightly sprinkled with cinereous pollen so that it is less shiny than the following segments, its sides and caudal margin almost wholly white pollinose; third segment with a cinereous pollinose stripe, dilated cephalad, obsolete caudad; the sides, the caudo-lateral angles, and the lateral portions of the caudal margins of segments 3, 4, and 5 are white pollinose; the sixth segment has its lateral margins and its caudo-lateral angles white pollinose. The tibiae are between a brown and a yellow color, seeming now one and now the other according to the incidence of the light. Femora black except the extreme bases and apices, which are yellow; they are wholly pollinose except the mesal surface of the posterior pair, which is shining; I can see no spines or pile on either femur. The awl-shaped terminal piece of the ovipositor is straight. Wings hyaline; veins black; stigma brown; small cross vein at junction of basal and middle thirds of discal cell; third costal segment shorter than fourth.

Division 3.

1. Stigma not colored. 2
2. Small cross vein at or apicad the middle of discal cell . . . 3
 - Small cross vein at basal fourth or fifth of discal cell . . . 10
 - Small cross vein before the middle but beyond the first third of discal cell 22
3. Eyes of the male in contact near the middle of front for a greater or less distance 4
4. Abdomen, especially the fifth segment, with short, erect black bristles 5
 - Abdomen with delicate whitish hairs or almost naked . . . 6
5. Humeri yellow. Hypopygium asymmetrical; looked at from the left it is as long as the fifth segment, from the right it is shorter than the fifth; on its caudal end is an oblique oval depression which is usually very distinct. Legs black, grayish pollinose; apices of femora, basal third of tibiae, and tarsi except last joint yellow; hind femora shining black on the mesal surface. Wholly greenish black, lightly gray pollinose, pollen thickest on first and fifth abdominal segments. Antennae black, very delicately whitish pubescent; third joint with a rather long drawn out white point. Wings hyaline; veins

black; third costal segment one half the fourth. Length 3.5 to 4 mm *similis* sp. nov.

This species is very like *P. sylvaticus* Meig., from which its pollinosity and the form of its hypopygium clearly separate it. The terminal segment of the ovipositor is straight, awl-shaped, and about as long as the hind tibiae. I have eleven males, collected by G. R. Pilate at Tifton, Ga., in Oct. and Nov., and two females, collected by C. F. Baker in Alabama.

6. Tarsi yellow, only the last joint black 8

8. Humeri yellow; front of male very small, silvery pollinose, without depression. Thorax and scutellum shining greenish black, dusted with brown pollen in the middle and towards the cephalic border. Hypopygium small, hardly half as long as the fifth segment; its rima oblique and to the right of the median line. Terminal piece of ovipositor straight and about as long as the hind tibiae. Wings hyaline; veins black; fourth costal segment hardly twice the third. Abdomen greenish black, shining. Legs black; the very apex of the femora and base of the tibiae yellowish; tarsi brownish yellow, toward the tip black. Halteres with yellow knob and brownish peduncle *subvirescens* Lw.

In the Loew collection a single rubbed male. I have numerous specimens, of both sexes, from New Bedford, Mass., Tifton, Ga., and Opelousas, La.

10. Males 11

11. Eyes not in contact, front not swollen.

Shining black, lightly white pollinose. Abdomen with a large yellow spot on each side; fifth and sixth segments large. Legs and coxae yellow except the basal two thirds of anterior coxae black. Length 4 mm.

Face and ventral half of front silvery pollinose. Antennae black, third joint yellow and very finely white pubescent, its apex prolonged in a white point. Thorax shining black, very lightly white pollinose especially near the humeri. Scutellum shining black. Metanotum and pleurae somewhat whitish gray pollinose. First abdominal segment black with a transverse yellow fascia at the cephalic border; second segment black except the caudolateral angles, which are yellow; incisure between second and third segments yellow; third and fourth segments black on the middle of the dorsum, their sides almost wholly yellow; incisures

between third and fourth and between fourth and fifth segments yellow; fifth segment wholly shining black, much longer and wider than fourth segment, beset with a few delicate, scattered, white hairs; sixth segment wholly black, somewhat grayish pollinose, quite as large as the fifth segment, not symmetrical, being larger on the left side, no visible cleft or depression on its apex. Wing grayish hyaline; veins black, yellow towards the base; small cross vein at basal fourth or fifth of discal cell; fourth costal segment much longer than the third. One male; Horse Neck Beach, Mass., Aug. 6 *flavomaculata* sp. nov.

12. Brown black, pollinose. Abdomen with segments one and five densely gray pollinose. Femora black, gray pollinose. Tibiae brownish yellow. Tarsi yellow except last joint black. Length 3.5 mm.

Eyes in contact. Face and the small, smooth frontal triangle silvery white. Antennae black, third joint silvery with a rather short sharp point. Dorsum of thorax and scutellum brown pollinose tending to gray pollinose at the sides and near the scutellum. Humeri yellow. Pleurae gray pollinose. Metanotum densely gray pollinose. First abdominal segment black on cephalic half, densely gray pollinose on caudal half; segments two, three, and four are blackish brown, very lightly gray pollinose on the dorsum, the pollen becoming gradually much thicker towards and on the sides; fifth segment very densely gray pollinose; on it there is visible in some lights a suggestion of a median, cephalo-caudal brown stripe; sixth segment shining black, only very slightly pollinose save at sides and on venter, about as large as the fifth segment, very slightly asymmetrical; no rima or depression can be seen; segments two, three, and four are of equal length, five is distinctly longer. Femora black, their extreme apices yellow, wholly gray pollinose except the mesal surface of the posterior, which is shining black. Tibiae appear to vary somewhat in color, according to the strength and incidence of the light, between a yellow and a brown; the anterior tibiae usually look brown except the extreme base which is yellow; the other tibiae look yellowish brown. Tarsi: anterior brown with yellow base; the others yellow with black tips. Wings grayish hyaline; veins black; small cross vein a little apicad the junction of the basal and middle thirds of the discal cell; third costal segment one half as long as the fourth. Halteres blackish brown, the middle of the peduncles yellowish *albofasciata* sp. nov.

One male, Opelousas, La. Collected by Mr. G. R. Pilate in May, 1897.

In the last two species, as in *P. fuscus*, the relative lengths of the third and fourth costal segments are very difficult to determine; moreover I cannot be quite sure that there is not a very little brown color in the stigma at its extreme apical angle. There is, however, so little of this color, if any, that there can be no impropriety in placing the species in this third division.

Only about ninety species of this family are known, of which fifty-eight are European. Undoubtedly there are many more species to be discovered.

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1. REVISION OF THE GENUS GYMNOLOMIA.

THE genus *Gymnolomia*, so far as known, is exclusively American and extends from the northwestern parts of the United States to Brazil. More than half its species, however, are confined to Mexico and Central America. The genus in its present circumscription has never been monographed. Kunth when founding it in 1820 described 4 species. De Candolle in the *Prodromus*, 5, 561 (1836) changes rather arbitrarily *Gymnolomia* to *Gymnopsis* under which 10 species are described of which several have since been referred to other genera. In 1873, Benth and Hooker f. ascribe to the genus *Gymnolomia* 16 species. Baillon in his *Histoire des plantes* regards the genus *Gymnolomia* as of doubtful value. Hoffmann in Engler and Prantl's *Nat. Pflanzenfamilien* maintains the genus and ascribes to it 20 species. Aside from the brief citations of the *Index Kewensis* by far the best bibliographic enumeration of the *Gymnolomias* is that of Hemsley (*Biol. Cent.-Amer. Bot.*, 2, 161) who cites literature and stations for 15 species, found in Mexico and Central America.

The present revision, including 37 recognized species and several varieties, has been chiefly based upon the specimens in the Gray herbarium, now largely supplemented by the incorporation of the Klatt herbarium. But through the kindness of Mr. Coville and Dr. Rose, the representation of the genus in the U. S. national museum has also been examined with profit.

The revision of the genus has presented three chief difficulties, viz.: — 1. The distinction of our own western and southwestern forms, which have, notwithstanding great diversity of foliage, pubescence, size of heads, and duration, been loosely grouped under *G. multiflora*. 2. The exact interpretation of the Central American *G. subflexuosa*, Benth., upon which must depend the varietal and specific nomenclature of some of the nearly related species. 3. The explanation and proper treatment of several large-headed

Mexican species which although they differ conspicuously among themselves, closely simulate a parallel series of *Viguieras*. As examples of this parallelism may be mentioned

G. ensifolia with the habit of *V. blepharolepis*.

G. megacephala, var. *simulans* with the habit of *V. excelsa*.

G. decumbens with the habit of *V. ghiesbreghtii*.

G. ghiesbreghtii with the habit of *V. buddleiaeformis*.

This simulation has various degrees of closeness. In *G. ghiesbreghtii* and *V. buddleiaeformis*, although the similarity is striking, the heads are always perceptibly smaller in the *Viguiera*. *G. megacephala* var. *simulans* and *G. decumbens*, however, so closely resemble *V. excelsa* and *V. ghiesbreghtii* respectively, that no satisfactory external characters have as yet been found by which to separate them. The examination of the achenes, however, at once reveals striking differences. The achenes are in the *Gymnolomias* more compressed, quite glabrous, and completely destitute of pappus. In the *Viguieras* on the contrary they are thickish, obtusely 4-angled, upwardly villous, and provided with two stout persistent awns and several short intermediate scales. Were the pappus difference the only one, these *viguieroid* *Gymnolomias* might logically be reduced to "*formae epapposae*" of their pappus-bearing counterparts in *Viguiera*, there being in *Calea* and elsewhere undoubted examples of the presence and absence of pappus in what must be regarded as conspecific types. In *Gymnolomia*, however, the difficulty is increased by the presence of other although slight differences in the form and pubescence of the achene.

The writers have carefully considered the possible readjustment of generic lines in such a manner as to bring together the species of similar habit, but they have failed to find any way in which this could be accomplished without the union of heterogeneous elements or an inordinate multiplication of genera founded upon rather trivial characters. It has accordingly seemed best to maintain the genus *Gymnolomia* in its traditional interpretation, although there may be some artificiality in the classification of the large-headed forms. Further collections will doubtless throw much light, if not upon the genetic affinities, at least upon the validity or inconstancy of the characters by which they are now separated.

GYMNOLOMIA, HBK. (Name from γυμνός, naked, and λῶμα, margin; taken by some to refer to the rays destitute of pappus, by others the achenes lacking pappus.) Heads small, medium-sized, or large, heterogamous, many-flowered, pedunculate, solitary or more often 3 to many at the ends of the branches. Involucre hemispherical or subcylindric; the bracts mostly numerous, in 2 to 4 series, very variable in size and thickness, the outer mostly narrow; receptacle elevated, conical, chaffy; pales conduplicate, entire or somewhat 3-toothed. Ray-flowers (5 to 20) in a single series, neutral; ligules linear to elliptic-oblong, exserted and spreading, entire and slightly toothed at the tip, yellow or very rarely crimson; disk-flowers numerous, perfect, regular, concolorous; tube short, cylindrical or somewhat dilated at the base, usually puberulent; throat cylindrical or narrowly campanulate; the limb 5-toothed. Achenes of the ray-flowers abortive and empty, of the disk-flowers obovoid, thickish, but more or less compressed laterally or 4-angled, rounded at the summit; pappus none or rarely present as a short cup or ring of 2 to 4 lacinate scales. Nov. gen. et spec., 4, 217, t. 373, 374; Gray, Proc. Amer. acad., 5, 182; Syn. fl., 1, pt. 2, 66, 269; Benth. and Hook. f., Gen., 2, 363; Hemsl., Biol. Cent.-Amer. Bot., 2, 161; Baill., Hist. pl., 8, 211; Hoffmann in Engl. and Prantl, Nat. Pflanzenf., 4, ab. 5, 233. Gymnopsis, DC., Prodr., 5, 561, in part. Heliomeris, Nutt., Journ. acad. Phila., ser. 2, 1, 171. Zaluzania, Sch. Bip., Flora, 1861, p. 553; 1864, p. 216, in part.—Nearly 40 species, chiefly perennial herbs, in habit passing almost imperceptibly from plants of the *Perymenium* type to others of the *Tithonia* type. The following arrangement is believed to show approximately the natural affinities of the species.

Subg. 1. **CALANTICARIA**. Corolla-tube in the disk-flowers considerably dilated at the very base, the expansion, thus developed, forming a sort of cap over the summit of the achene: stems shrubby, except perhaps in *G. tripartita*: heads medium-sized; scales of the involucre mostly narrow.

* Leaves rather small, opposite, entire or merely undulate: scales of the involucre oblong, obtuse.

1. *G. GREGGII*, Gray. Closely branched shrub: leaves opposite, ovate, obtuse, cuneate to short petioles, pale green above, white-tomentulose beneath, 2 to 3 cm. long (incl. petiole), 1 to 1.8 cm. broad: peduncles long, mostly solitary at the ends of the branches.—

Proc. Amer. acad., 15, 36. — Northern Mexico, *Gregg*, no. 382; and on limestone hills Carneros Pass, Coahuila, *Pringle*, no. 2387.

* * Leaves alternate, larger, subentire.

2. *G. CINERASCENS*, Benth. and Hook. f. Dichotomous under-shrub with brownish purple soft-pubescent leafy stems terminating in compound irregular many headed corymbs: leaves ovate-elliptic, 5 to 6 cm. long, 3 to 4 cm. broad; the upper oblong, attenuate at each end, acute, minutely serrulate, subtriplinerved, pubescent above: heads borne on white clavate peduncles: ligules (white?) neutral: achenes glabrous, without pappus. — Gen., 2, 362; Hemsl., l. c., 161. *Zuluzania cinerascens*, Sch. Bip., Flora, 1864, p. 219, whence above desc. is compiled. — S. Mexico, Mineral del Monte, *Ehrenberg*, no. 346. We have not been able to see specimens of this species but from Schultz statement that the corolla is cucullate over the achene there can be little doubt that it is to be referred to Subg. Calanticaria.

* * * Leaves lobed, scales of the involucre lance-linear, acute to attenuate.

3. *G. PINNATILOBATA*, Benth. and Hook. f. Shrub: branches covered with a fine white at length deciduous pubescence: leaves pinnately several-lobed, pale green above, white-tomentulose beneath, 3 to 6 cm. long (including the winged petiole), half as broad; lateral lobes blunt, the lower large, the upper smaller. — Gen., 2, 364; Hemsl., l. c., 163. *Zuluzania pinnatilobata*, Sch. Bip., Flora, 1864, p. 219. — South Mexico, Tehuacan, *Liebmann*, no. 384, *Pringle*, no. 6252; Cordillera of Oaxaca, *Galeotti*, no. 2124, acc. to Hemsl.; limestone mesas, San Antonio, Oaxaca, *Pringle*, no. 5731. Mr. E. W. Nelson's no. 1638 from Oaxaca forms a puzzling intermediate between this and the otherwise well-marked *G. tripartita*.

4. *G. TRIPARTITA*, Robinson and Greenman. Stems smooth and glabrous: leaves deeply and palmately 3-parted; segments narrow, oblong, acute, often bluntly lobed near the base, the lateral sometimes very short or in upper leaves wanting, paler but green beneath: heads numerous, slender-peduncled in an open corymb. — Amer. journ. sci., ser. 3, 50, 154. — Oaxaca, Cuicatlan, *L. C. Smith*, no. 239; Jayacatlan, *L. C. Smith*, no. 386.

5. *G. TENUIFOLIA*, Benth. and Hook. f. Low shrub, 1 m. or more high: leaves numerous, deeply 3-fid or pinnatifid with lobes few, linear to lance-linear, acute, green above, finely white pubes-

cent beneath, the margins revolute: peduncles long, solitary at the ends of the branches; bracts of the involucre attenuate. — Gen., 2, 364; Hemsl., l.c., 163; Gray, Syn. fl., 1, pt. 2, 269. *Helioomeris tenuifolia*, Gray, Pl. Fendl., 84; Pl. Wright., 1, 107; 2, 87. — Southwestern Texas, rocky cliffs of Turkey Creek and beyond the Pecos, *Wright*, no. 329; rocky hills near Eagle Springs, *Wright*, no. 1223, *Sutton Hayes*, no. 444; at Presidio, *Havard*, El Paso, *Gray, Jones*, no. 4347; Santa Maria, *Nealley*, no. 163; and Chénantes Region, *Nealley*, no. 576; New Mexico in the Organ Mts., *Wooton*, no. 442; Mexico, Tamaulipas, *Berlandier*, nos. 814, 2234, *E. W. Nelson*, no. 4507; Saltillo, *Gregg*, nos. 21, 125; Coahuila, *Palmer*, nos. 620 to 624 (coll. of 1880), *Pringle*, no. 148; Chihuahua, *Thurber*, no. 834; San Luis Potosi, *E. W. Nelson*, no. 4532.

Subg. 2. EUGYMNOLOMIA. Corolla-tube in the disk-flowers cylindrical or slightly enlarged at the base; leaves (often serrate) not lobed; stems mostly herbaceous.

* Heads usually numerous, pedunculate, small or more often medium-sized (disk 7 to 12 mm. broad excl. of the rays); involucre scales linear, acutish to attenuate: leaves mostly lance-linear to linear, rarely oblong.

+ Outer involucre bracts herbaceous, attenuate (1.1 to 1.7 cm. long) coarsely ciliate on the margin, otherwise nearly or quite glabrous: ligules 5 to 9, elliptic, showy: Georgia.

6. *G. PORTERI*, Gray. Tall slender erect corymbosely branched annual with lance-linear to linear chiefly alternate leaves coarsely ciliate near the base; those of the stem 6 to 12 cm. long: disk narrowly conical; pales striate, entire, pungent. — Proc. Amer. acad., 12, 59; Syn. fl., 1, pt. 2, 269; Meehan, Native fl., ser. 1, 2, 137, pt. 35; Chapm., Fl., ed. 3, 251. *Rudbeckia* ? *porteri*, Gray, Pl. Fendl., 83; Chapm., Fl., ed. 3, 228. — Growing on scanty humus in hollows and crevices of granite rock on the summit and slopes of Stone Mountain, Georgia, where curiously local, *Porter* (type, in herb. Gray), *Ravenel, Hendee, Cumby, J. D. Smith, Curtiss*, no. 1434, *Small*; fl. August to October.

+ + Outer involucre bracts (rarely elongated) usually appressed-pubescent or even hoary: ligules 10 to 14, linear or oblong: western U. S. and Mexico.

7. *G. MULTIFLORA*, Benth. and Hook.f. Perennial: stems usually several (1.5 to) 9 or 12 dm. high, from a thickish lignescent stock, finely striate and covered with a very short-appressed grayish pubescence: leaves lanceolate or linear-lanceolate and acutish to lance-oblong or oblong and obtuse, 4 to 7 cm. long, 4 to 20 mm.

broad, attenuate at the base, finely pubescent, becoming scabrous especially above: heads (exclusive of rays) 1.2 cm. in diameter; involucre scales canescent with appressed hairs. — Benth. and Hook. f., acc. to Rothr. in Wheeler Rep., 6, 160, as to synonym; Gray, Syn. fl., 1, pt. 2, 269 only in part. *Helioomeris multiflora*, Nutt., Journ. acad. Phila., ser. 2, 1, 171; Wats., Bot. King exp., 170, at least in great part. — Rocky mountains and plains of Idaho, *Palmer*, no. 422; Wyoming, *Hayden*, no. 34, *Tweedy*, *Burglehaus*, *A. Nelson*, nos. 39, 1064, 2663; Colorado, *Rothrock*, no. 551, *Parry*, no. 420, *Greene*, no. 194, *Jones*, *C. S. Shelton*, nos. 152, 468, *Cowen* (low and many-stemmed), *Miss Eastwood* (coll. July, 1889); Utah, *Jones*, nos. 5820, 5996; Nevada, in the Uintas, *Watson*, no. 606; New Mexico, *Wootton*, no. 484; California, *Gambel*, *Co-ville* and *Funston*, no. 806; and in the Rocky Mountains, without locality, by *Gordon*, *Burke*, and by *Frémont*, no. 121. Toward the southwest this species passes into somewhat narrower-leaved forms (Utah, *Ward*, nos. 647, 652, *Jones*, no. 5996 r; Arizona, *Palmer*, coll. of 1869 without number and no. 241 coll. of 1877, *Knowl-ton*, no. 6; S. E. California, *Purpus*, no. 5025), which, however, retain their perennial character.

8. *G. longifolia*. Erect paniculately branched annual: stem single, 6 to 12 dm. high, finely pubescent with appressed hairs: leaves lance-linear or oblong-linear, narrowed at both ends, those of the stem 8 to 11 cm. long, 5 to 10 mm. broad, entire or obscurely and remotely crenate-serrate, finely pubescent on both surfaces, becoming very scabrous and tuberculate-hispid above, often ciliate toward the base; peduncle and involucre bracts covered with fine appressed pubescence; heads numerous, in size and floral characters essentially like those of *G. multiflora*. — *G. multiflora*, Hemsl., l. c., 162, as to Mex. pl.; Gray in Wats., Proc. Amer. acad., 21, 432; Syn. fl., 1, pt. 2, 269, in part; not Benth. and Hook. f. *Helioomeris multiflora*, Gray, Pl. Wright., 1, 107; 2, 87, in part, not Nutt. — W. Texas, *Wright*, no. 328, *Howard*, *Nealley*, no. 432 (depauperate), *Dr. Smart*, no. 422; New Mexico, "on pine hills between the copper mines and the mimbres," *Wright*, no. 1221; Burro Mts., *Rusby*, no. 172; Arizona, Rucker's Valley, *Lemmon*, nos. 345, 2765, and 383 (a form with double flowers); Nagle's Ranch, *Jones*, no. 6054 p.; Mexico, between San Luis Potosi and Tampico, *Palmer*, no. 1102; hills and plains near the town of Chihuahua, *Pringle*, no. 615; S. W. Chihuahua, *Palmer*, no. 392; Strawberry Valley,

Chihuahua, *Hartman*, no. 777; vicinity of Durango, *Palmer*, no. 754; Chiapas, *Ghiesbreght*, no. 63. Types in herb. Gray.

9. *G. annua*. Annual, slender, often branched from the base, 3 to 5 dm. high, copiously branched above: leaves linear or nearly so, finely appressed-pubescent and even somewhat canescent, slightly ciliated at the base or not at all, the cauline 4 to 7 cm. long, 2 to 3 mm. broad, the rameal smaller: pubescence on the peduncles and on the involucre bracts fine and appressed; heads rather small, usually 7 to 10 mm. in diameter (exclusive of rays): rays 10 to 14, yellow, 4 to 12 mm. long: otherwise like *G. multiflora*. — *G. multiflora*, Gray, Syn. fl., 1, pt. 2, 269, in part, not Benth. and Hook. f. *G. multiflora*, var. *annua*, Jones, Proc. Calif. acad. sci., ser. 2, 5, 698. *Helioomeris multiflora*, Gray, Pl. Fendl., 84, as to pl. of Wislizenus; Pl. Wright., 2, 87, in part, not Nutt. — W. Texas, *Wright*, no. 334, *Pope*; New Mexico, on sides of mountains near the copper mines, *Wright*; Arizona, on sandy river bottoms, near Ft. Whipple, *Coues* and *Palmer*, no. 559, at Patano, *Pringle*; near Defiance, *Marsh*, no. 229; Arizona, *Knorrton*, no. 283, *Wilcox*, no. 455, *Rothrock*, no. 779; Mexico, at Llanos, *Wislizenus*; in Sonora, *Wright*, no. 1220, *F. E. Lloyd*, nos. 410, 411. Distinguished from *G. multiflora* by its annual root, much narrower leaves, somewhat smaller heads, shorter rays and distinctly Sonoran range; from *G. hispida*, var. *ciliata* less satisfactorily by the different pubescence of its leaves and involucre scales.

10. *G. hispida*. Probably annual, 6 to 8 dm. high, densely hispid and hoary throughout with long stiff white hairs, those of the stem and peduncles widely spreading: leaves alternate, narrow, linear, 5 to 7 cm. long, 3 or 4 mm. broad, thickish, channeled above: involucre bracts considerably exceeding the disk, hirsute and hoary: flowers as in *G. multiflora*. — *Helioomeris multiflora*, var. *hispida*, Gray, Pl. Wright., 2, 87, as to typical canescent form. — Low damp soil, near Sta. Cruz and San Bernardino, Sonora, *Wright*, no. 1220 in part. In the almost shaggy pubescence of the leaves and copious spreading pubescence of the peduncles this form differs rather markedly from the others here enumerated, but it certainly passes to

var. *ciliata*. Slender annual, commonly branched from the base, 3 to 6 dm. high: stems with sparse spreading pubescence or nearly glabrous below: leaves linear, green, conspicuously ciliate

for the greater part of their length: pubescence of the peduncles sparing, mostly appressed; involucre scales ciliate but scarcely pubescent otherwise. — *Helionis multiflora*, var. *hispida*, Gray, l. c., in part, i. e., as to greener forms. — S. Utah at Beaver, *Palmer*, no. 245; New Mexico, Zuni Mts., *Sitgreaves Exp.*, San Antonita, *Bigelow* in part; S. California at Sta. Monica, *Hasse*; Sonora, Mexico, *Wright*, no. 1222 in part.

* * Heads small or medium-sized; involucre scales linear and acute or the inner narrowly oblong and obtusish: leaves ovate or ovate-lanceolate: perennials so far as the duration is known.

+ Heads small and numerous, corymbose at the ends of the branches: leaves petioled (shortly so in var. *abbreviata*).

→ Leaves distinctly serrate.

= Pappus none: Mexico to Venezuela.

11. G. PATENS, Gray. Smoothish: stems flexuous, reclining, becoming 5 m. in length, at length soft-woody at the base, striate-angulate, sparingly and minutely appressed-pubescent; leaves ovate, acuminate, serrate, thin, obliquely truncate at the base, finely pubescent, more or less scabrous above; petioles slender, 1 to 3.2 cm. long; peduncles slender, finely appressed-pubescent; involucre cylindric, 5 mm. in diameter; outer scales lanceolate acute or attenuate, the inner longer, oblong, striate, obtusish: ligules 6 to 10, 1 cm. long, yellow turning whitish during or after drying; disk-flowers, 30 to 35. — Proc. Amer. acad., 5, 182; Hemsl., Biol. Cent.-Amer. Bot., 2, 163. ? *Wedelia cordata*, Hook. and Arn., Bot. Beech., 435. *Microcephalum ehrenbergianum*, Sch. Bip., and *Gymnolomia ehrenbergiana*, Klatt, Leopoldina, 23, 90. *Montanoa thomasi*, Klatt, Abh. naturf. gesell. Halle, 15, 328. — State of San Luis Potosi, *Palmer*, no. 1099, *Pringle*, no. 3937; Orizaba, *Schaffner*, *Botteri*, no. 497, 810, *Thomas*; Wartenberg in Huasteca, *Ervendberg*, no. 95; Oaxaca, El Pariánetla, *Conzatti* and *González*, no. 906; Guatemala, von *Tuerckheim*, no. 287.

var. *ABBREVIATA*, Robinson and Greenman. Stems 1 to 2 m. long, sparingly appressed-pubescent: petioles very short, 4 to 6 mm. in length; leaves somewhat narrower and thicker than in the type: pappus none. — Proc. Amer. acad., 29, 387. — Jalisco at Tequila, *Pringle*, no. 4595; Guerrero, between Chilapa and Tixtla, altitude 1,600 to 2,100 m., *E. W. Nelson*, no. 2164.

var. *GUATEMALENSIS*. With copious spreading pubescence on the stem: pedicels 1 to 2.5 cm. long: pappus none. — Guatemala,

San Miguel Uspantán, Dept. Quiché, *Heyde and Lux*, no. 3370 of Mr. J. Donnell Smith's sets.

var. brachypoda. Pubescence, at least on the upper part of the stem, spreading: pedicels very short (2 to 5 mm. in length): pappus none. — Guatemala, Alta Verapaz, altitude 1,300 m., *von Tuerckheim*, no. 852 of Mr. J. Donnell Smith's sets; also in Colima, S. W. Mexico, *Palmer*, no. 1223 (coll. of 1891).

var. macrophylla. Pubescence of the stem copious, spreading: leaves (1.5 dm. long, 8 to 10 cm. broad) much larger than in the other forms of the species, subcrenately serrate: pappus none. — Venezuela near Tovar, at 1,000 m. altitude, *Fendler*, no. 686.

12. *G. COSTARICENSIS*, Benth. Habit, foliage, and pubescence as in *G. patens*: heads larger (disk-flowers about 50); involucre campanulate: pubescence fine, appressed or subappressed: rays about 10: achenes of the disk-flowers destitute of pappus but sometimes crowned with an obscure ring or rim. — Benth. acc. to Klatt, Bull. soc. bot. Belg., 31, 199, at least as to pl. of Oersted (Pittier's no. 2614, referred to this species by Klatt, is, in herb. Klatt, *Baltimora scolosperum*, Steetz!). *G. rudbeckioides*, Hemsl., Biol. Cent.-Amer. Bot., 2, 163, in part, probably not HBK. *Gymnopsis? costaricensis*, Benth. in Oerst., Vidensk. meddel., 1852, p. 90. *G. vulcanica*, Steetz in Seem. Bot. herald, 157. *Aspilia costaricensis*, Klatt, l. c., 201, as to synonym. and Pittier's no. 3276 in part. — Costa Rica, Aguacate, and Ujaras, *Oersted*; Rodeo de Pacaca, *Pittier*, no. 3276 in part, San Francisco de Guadalupe, *Tonduz*, nos. 7251, 7288; Rio Maria near S. José, *Tonduz*, no. 7271; Panama Boquete, Veraguas, *Seemann*, no. 1588.

= = Pappus none: Peruvian.

13. *G. RUDBECKIODES*, HBK. Of habit and foliage of the last two species but with short petioles (4 to 6 mm. long), spreading pubescence, and (ex icon.) more axillary or irregular (less definitely corymbose) inflorescence. — Nov. gen. et spec., 4, 219, t. 374. — Temperate regions, Agavaca, Peru, *Humboldt* and *Bonpland*. Not seen by the writers, who have been unable to match satisfactorily the original description and figure of this species with any Mexican or Central American plant.

= = = A definite pappus present, consisting of several fimbriate scales.

14. ? *G. SUBFLEXUOSA*, Benth. and Hook. f. Habit, foliage, pubescence, and inflorescence much as in *G. patens*, from which we are

able to separate it solely by the pappus.— Gen., 2, 364; Hemsl., l. c., 163. *Wedelia subflexuosa*, Hook. and Arn., Bot. Beech., 435.— Realejo, Nicaragua, *Sinclair*; Orizaba, *Botteri*, no. 435 (acc. to Hemsl.). To this species of which we have seen but a single achene we refer with doubt specimens from the following localities: Vera Cruz, Valley of Cordova, *Bourgeau*, no. 1961; Oaxaca, Jayacatlan, *L. C. Smith*, no. 896, Monte Alban, *Pringle*, no. 4859, *C. L. Smith*, no. 244, Valley of Etna, *L. C. Smith*, no. 849, *Alvarez*, no. 723; Costa Rica, Prov. of San José, *J. Donnell Smith*, no. 4871. A better knowledge of the type of this species will doubtless justify at least a varietal separation of some of the specimens here mentioned.

↔ ↔ Leaves entire or nearly so, canescent-sericeous beneath.

15. *G. CANESCENS*, Robinson. Leaves opposite, ovate, subtruncate or subcordate at the base, acute or often obtuse at the apex, finely gray pubescent above, silky and silvery beneath; petioles 2 cm. long: branches of the naked inflorescence long, bearing few clustered heads at their ends.— Proc. Amer. acad., 27, 174.— San Luis Potosi, brackish marsh, Las Tablas, *Pringle*, no. 3611, alkaline plains, Hacienda de Angosture, *Pringle*, no. 3763.

+ + Heads somewhat larger (of medium size) rather few, mostly solitary or borne by 3's at the ends of the branches.

↔ Outer bracts of the involucre shorter than or little exceeding the inner: species of Mexico, Cent. America, and Andean South America.

= Leaves sessile or petioles short (2 to 8 mm. long).

α. Pappus none: species of Mexico.

16. *G. OVATA*, Gray. Stem 4 to 8 dm. long or more, covered with a short spreading pubescence: leaves ovate, subsessile, 3 to 7 cm. long, 2 to 4 cm. broad, serrate, mostly acute: heads 3 to 8, long, unequally long-peduncled, 1.5 to 1.8 cm. in diameter (exclusive of rays), many-flowered; the bracts of the involucre narrow, loose, very numerous.— Proc. Amer. acad., 19, 4.— Chiapas, *Ghesbreght*, no. 554; Oaxaca, Sierra de San Filipe, altitude 1,800 to 2,500 m., *Pringle*, no. 5674, *Conzatti* and *González*, no. 551.

17. *G. LIEBMANNII*, Klatt. Smaller: leaves sessile, cordate, green on both sides, 2 cm. long, nearly as broad: heads few, 1 or 2 or perhaps 3 at the ends of the branches; involucre 6 mm. in diameter; bracts 2-seriate, rather few, lanceolate; rays about 9, conspicuously 5-nerved.— Leopoldina, 23, 90. *Microcephalum lieb-*

mannii, Sch. Bip., acc. to Klatt, l. c.—S. Andres, Mecatlan, Mexico, *Liebmann*, no. 588. Type in the herbarium of the Botanic garden of Copenhagen; a tracing and fragment in herb. Gray.

b. A rudimentary pappus generally present as a short-fringed cup: South American species.

18. *G. TENELLA*, HBK. Prostrate, much-branched: stems slender, hard: leaves opposite, ovate, subcordate, obtusish, thick, rugose, very scabrous above, short-petioled, serrate or serrulate, 2 to 5 cm. long: heads solitary, terminal, on filiform peduncles; involucre 8 to 10 mm. in diameter; the bracts oblong-lanceolate, canescent-pubescent; disk achenes obovate, appressed-pubescent, somewhat contracted above into the at length obscure pappus-cup.—Nov. gen. et spec., 4, 218, t. 373; Klatt in Engl. Jahrb., 8, 42.—New Granada near Ibague and Contreras, *Humboldt*; in bushy undergrowths and on savannas of the Rio Dagua, Cauca, altitude 1,000 to 1,800 m., *Lehmann*, nos. 1956, 2865, 2994.

19. *G. HONDENSIS*, HBK., l. c., 218. From description close to if not identical with the preceding: leaves said to be subacuminate at the apex and rounded at the base.—Torrid regions of New Grenada near Honda, *Humboldt*. Sprengel (Syst., 3, 610) reduces this species to *G. tenella*, where it may well belong.

20. *G. TRIPLINERVA*, HBK. Branches terete, smooth, glabrate, the younger with appressed pilosity: leaves opposite, ovate, narrowly subacuminate, acute at the base, crenate-dentate, reticulate-veiny, 3-nerved, hispidulous with appressed hairs on both surfaces, about 6 cm. long, half as broad; petioles 6 to 8 mm. long: heads solitary on long appressed-pubescent peduncles; involucral bracts numerous, appressed-pubescent, the outer slightly exceeding the inner: disk-flowers and achenes unknown.—Nov. gen. et spec., 4, 219.—On high plains of Bogota, U. S. Colombia, *Humboldt*. Not seen by the writers, the descr. compiled.

= = Petioles longer (8 to 20 mm. in length): ligules rather showy, 1 to 2 cm. long.

a Rays about 12, narrow, strongly carinate or conduplicate.

21. *G. CRUCIATA*, Klatt. Tall erect shrub, 3 m. high: branches tetragonal, rough: leaves ovate-oblong, shortly cuneate or one-sided at the base, 7 cm. in length, half as broad; the petioles 1 cm. long: rays about 12.—Bull. Herb. Boiss., 4, 480.—Near Castañal, U. S. Colombia, *Sonntag*, no. 3, June, 1888. Type in herb. Univ. of Zurich; a head and sketch in herb. Gray.

b. Rays 8 to 10, not conspicuously carinate or conduplicate: South American.

22. *G. QUITENSIS*, Benth. and Hook. f. Shrub with rather copious pubescence: leaves all opposite, acuminate, from subcordate to shortly cuneate at the base, 4 to 9 cm. long, half as broad: heads cymose, the peduncles rather short, 2 to 2.5 cm. long, much exceeded by the leaves. — Gen., 2, 364. *Andrieuxia quitensis*, Benth., Pl. Hartw., 206. — Andes of Ecuador, *Hartweg*, no. 1142, *Hall*, *Couthouy*.

→ → Outer bracts of the involucre elongated, the inner short: species of Central Brazil.

23. *G. KUNTHIANA*, Baker. Erect perennial pubescent herb: leaves petiolate, ovate, serrate, the upper alternate: involucre 1 to 1.2 cm. in diameter; outer bracts oblong, large, unequal, acute, 1.2 to 2.4 cm. long: ligules 10 to 15. — Baker in Mart. Fl. Bras., 6, pt. 3, 172. *Gymnopsis kunthiana*, Gardner in Hook. Lond. journ. bot., 7, 292. — Dry mountainous regions near Conceição Goyaz, Brazil, *Gardner*, no. 3846.

*** Heads and involucre as in the last group: leaves (all opposite) narrowly lanceolate: pappus none: South American.

← Pedicels bracteolate.

24. *G. GOEBELII*, Klatt. Finely and cinereously appressed-pubescent: leaves rather small: branches terminated by 3-headed cymes; pedicels long and slender, bearing above the middle two subulate bractlets; heads 1.2 to 1.5 cm. broad exclusive of the 16 to 20 narrow linear rays. — Klatt in Goebel, Pflanzenbiologische schilderungen, 2, 49. — Dry slopes near the small town of Muru-chies, Venezuela, *K. Goebel*.

← ← Pedicels naked.

25. *G. HIRSUTA*, Klatt. Branching shrub, scarcely or not at all canescent: leaves long-lanceolate, caudate-attenuate, obtusish at the base, 7 cm. long, 1.5 cm. broad, bullate-rugose above, veiny and pubescent beneath: ligules about 12, oblong, 5 mm. broad. — Klatt in Engl. Jahrb., 8, 42 (1886). — Among shrubs, borders of woods, Tungu-ragua, Ecuador, altitude 2,200 m., *Lehmann*, October, 1879, no. 360 a.

**** Heads large, but ligules short; involucre scales oblong, the tips slightly squarrose; peduncles long: leaves oblong or elliptic, sessile, harsh in texture and hirsute: perennial herb.

26. *G. PARKINSONII*, Hemsl. Erect, coarsely pubescent and

scabrous: leaves alternate or scattered (the middle ones occasionally verticillate), 6 to 13 cm. long, 1.2 to 3.4 cm. broad, prominently 3-nerved: heads on long stout ascending alternate peduncles, subglobose, 2 to 2.5 cm. in diameter. — Biol. Cent.-Amer. Bot., 2, 163. *G. rudis*, Gray, Proc. Amer. acad., 22, 424. *G. rudis*, var. *minor*, Rob. and Greenm., ibid, 29, 387 (small form). — The type (in herb. Kew), collected in Mexico, without locality, by *Parkinson*, has brownish-purple flowers. This form is represented also by *Palmer's* no. 531 from the Rio Blanco, Jalisco, *Pringle's* no. 4584 from rocky hills near Tequila (small form), and *Rose's* no. 3031, coll. between Bolaños and Guadalajara, and no. 3700 coll. at Bolaños. This typical form is connected by variegated transitions with a forma *flaviflora* in which both disk- and ray-flowers are golden yellow. The latter form is represented by *Pringle's* no. 2460, from hillsides near Guadalajara, *Palmer's* no. 533 from the Rio Blanco, and *Rose's* no. 2827, coll. between Colotlan and Bolaños, Jalisco. No morphological differences between the individuals with brown-purple flowers and those with yellow flowers have been detected.

***** Heads large (1.6 to 1.8 cm. broad excl. of rays), terminal, solitary; involucre bracts narrow, lance-linear, attenuate: rays long: leaves lance-oblong.

27. *G. serrata*. Perennial: stems several, 5 dm. high, unbranched, striate, terete, puberulent, leafy, 1 (-2)-headed: leaves lance-oblong, opposite or alternate, attenuate, conspicuously serrate, shortly petiolate, scabrous-puberulent above, scarcely paler, pubescent, and reticulate veiny beneath, 6 to 12 cm. long, 1 to 2 cm. broad: involucre bracts herbaceous, lance-linear, attenuate, appressed-canescant-pubescent especially on the mid-nerve, 1 to 1.2 cm. long: rays deep yellow, oblong, 1.5 to 2.5 cm. long, 5 to 8 mm. broad: disk-corollas yellow, essentially glabrous, 6 mm. long: immature achenes 4 mm. long, glabrous, destitute of pappus. — Collected in S. W. Chihuahua on Mt. Mohinora, 1 September, 1898, *E. W. Nelson*, no. 4891. Types in herb. U. S. nat. museum and herb. Gray.

***** Heads of medium size, most of them sessile or shortly peduncled in few many-headed leafy corymbs: involucre bracts ovate, obtuse, conspicuously squarrose: leaves ovate, sessile.

28. *G. squarrosa*, Benth. and Hook. f. Erect perennial herb, simple below, coarsely and copiously pubescent: leaves serrate

100

scabrous above, paler and somewhat canescent-pubescent beneath, 5 to 7 cm. long: ligules (about 13) 1 to 1.3 cm. long.—Gen., 2, 362; Hemsl., l. c.; Gray in Wats., Proc. Amer. acad., 22, 424. *Zaluzania squarrosa*, Sch. Bip., Flora, 1864, p. 217. — Ravines near Guadaluajara, Jalisco, *Oliva* (1854), *Palmer*, nos. 486, 741 (1886), *Pringle*, nos. 2194, 2474 (1888–89). Flowering from September to November.

***** Heads small or medium-sized, slender-peduncled: involucre bracts (all but a few of the outermost) broad, obovate or oblong, mostly obtuse or rounded at the apex: leaves ovate or lanceolate to linear-oblong.

— Scales of the involucre not canescent.

29. *G. LATIBRACTEATA*, Hemsl. Stems terete, striate, purple, alternately branched above, sparingly scabrous-pubescent: leaves alternate (so far as known), lanceolate, attenuate at each end, short-petioled, obsoletely serrate, 6 to 8 ("to 13") cm. long, 1 to 3 cm. broad: peduncles 5 to 7 cm. long, 1-headed; heads (excl. of ligules), 1.5 cm. in diameter; involucre campanulate: rays few, 1.2 to 1.4 cm. long.—Hemsl., l. c., 162. — Cerro Pinar, North Mexico, *Seemann*, no. 1485. Collected but once.

— Scales of the involucre canescent.

30. *G. ENSIFOLIA*, Benth. and Hook. f. Stems slender, terete, strigillose, and scabrous: leaves opposite, sword-shaped, 1 to 1.2 dm. long, 1 to 1.5 cm. broad, gradually narrowed from near the sessile base to the attenuate apex, very scabrous above, pale beneath: heads cymose; involucre bracts all rounded at the apex, the outer much shorter.—Gen., 2, 364; Hemsl., l. c., 161. *Montagnea ensifolia*, Sch. Bip. in Seem. Bot. herald, 304. *Zaluzania ensifolia*, Sch. Bip., Flora, 1864, p. 216. — Sierra Madre, Northern Mexico, *Seemann*, no. 2007 in part; Tepic, *Palmer* (coll. of 1892).

31. *G. SERICEA*, Klatt. "Suffrutescent": leaves chiefly opposite, ovate, shortly connate-petiolate, entire, 3-nerved, acute, acuminate, 3 to 4 cm. long, half as broad, above green and scabrous, beneath silky canescent: heads 1.2 cm. in diameter; involucre bracts biseriate, oblong, subequal: rays about 20, narrowly oblong.—*Leopoldina*, 23, 90. *Microcephalum sericeum*, Sch. Bip. acc. to Klatt, l. c.—Mexico, without locality, *Liebmman*, no. 609. Type in herb. Botanic garden of Copenhagen; excellent drawing and some fragments in herb. Gray.

***** Heads large (1.7 to 7 cm. broad excl. of rays); involucre bracts broad, the inner large, spatulate with rounded apex: perennial herbs: leaves lanceolate to oblong or ovate; petioles short winged, or almost none.

+ Leaves oblong-lanceolate, pale beneath.

32. *G. GHIESBREGHTII*, Hemsl. Erect, simple or branched from the base, 6 to 15 dm. high: leaves all alternate or some opposite, serrate or serrulate, mostly acute at each end, 5 to 10 cm. long, 1 to 4 cm. broad: heads few, 2 to 2.5 cm. in diameter; outer scales short, squarrose: ligules about 20, golden yellow, 2 cm. long. — Hemsl., l. c., 162. — South Mexico, hills of Oaxaca, *Ghiesbreght*, nos. 385 (acc. to Hemsl.), 382, *Pringle*, no. 4963, *E. W. Nelson*, nos. 1371, 1464, *L. C. Smith*, no. 799, *Conzatti* and *González*, no. 553; Michoacan on wooded hills near Patzcuaro, *Pringle*, no. 3339.

+ + Leaves elliptical, green beneath.

33. *G. DECUMBENS*, Robinson. Stems several from a lignescent stock, decumbent, 4 to 5 dm. long: leaves chiefly opposite, 2.5 to 4 cm. long, half as broad, scabrous upon both surfaces: heads solitary or borne by threes at the summit of each stem; outer scales of the involucre ovate-lanceolate, acute, not squarrose, dark colored, covered with appressed white hairs. — Proc. Amer. acad., 26, 165. — Rocky hills, Tultenango, State of Mexico, *Pringle*, no. 3263 in part; Zacatecas between Bolaños and Guadalajara, *Rose*, no. 3044 (leaves somewhat longer).

The achenes of this species are perfectly glabrous, obovate-oblong, strongly compressed, striate, and completely destitute of pappus. It is now found that another plant of astonishing similarity was also collected and distributed under the type number (*Pringle's* no. 3263). While in all observed external characters it cannot be distinguished from the former, it has thick obtusely 4-angled mottled and pubescent achenes which are crowned with 2 (to 4) paleaceous awns and intermediate scales. The latter plant seems to be identical with *Viguiera ghiesbreghtii*, Gray.

+ + + Leaves ovate, large and broad.

↔ Petioles not auricled.

= Outer involucre bracts large, squarrosely spreading or reflexed, about as long as the inner ones, acute or acuminate.

34. *G. FLAVA*, Hemsl. Stems strigillose becoming hirsute with coarse spreading hairs toward the summit and upon the peduncles:

leaves 7 to 10 cm. long, 2 to 3 cm. broad, above scabrous, beneath hirsute upon the veins and finely canescent-pubescent upon the surface: heads (excl. the rays) 2.5 to 3.5 cm. in diameter: ligules about 15. — Hemsl., l. c., 161. — Oaxaca, *Ghiesbreght*, no. 216 (type in herb. Kew). We follow Dr. Gray in referring to this species *Ghiesbreght's* no. 383, from which the above characterization is drawn.

35. **G. megacephala**. Stems simple, striate, scarcely at all scabrous, covered with minute appressed hairs, also lanate in lines decurrent each from either side of the short winged petioles: leaves ovate-lanceolate with short slender caudate acumination, serrate, scabrous above, hirsutulous upon the veins, but green and glabrous upon the surface beneath, 8 to 12 cm. long, 2 to 4.5 cm. broad: heads terminal, solitary, about 7 cm. broad: no rays observed. — Collected between Tlapa and Ayusinapa, Guerrero, Mexico, altitude 1,380 to 1,700 m., 13 December, 1894, *E. W. Nelson*, no. 2105, distributed as *G. flava*.

var. **simulans**. Pubescence of the stem coarser, spreading: bases of the hairs enlarged, white, tuberculate: leaves somewhat larger, less pubescent, merely cuspidate at the obtusish tip: rays about 13, oblong, bright yellow, 3 cm. long, 7 to 10 mm. broad. — Collected on the Sierra de los Morones near Plateado, Zacatecas, altitude 2,300 m. 1 September, 1897, *Dr. J. N. Rose*, no. 2740. This variety closely simulates *Viguiera excelsa*, Benth. and Hook.f., which, however, differs technically and, as it appears, with constancy in its pubescent achenes which bear at the summit two conspicuous awns and some intermediate scales.

= = Outer involucre bracts much shorter than the large inner ones.

36. **G. PLATYLEPIS**, Gray. Hirsute shrub, 1 to 3 m. high: leaves chiefly opposite, acuminate or attenuate at each end, very scabrous above, paler and densely soft-pubescent beneath, 1 dm. long, 3-nerved from considerably above the base: peduncles thickened upwards; heads (excl. of rays) 2 to 3 cm. in diameter; ligules 15 to 20 in number, 2 to 3 cm. long. — Proc. Amer. acad., 19, 5; Klatt, Bull. soc. bot. Belg., 31, 199. *G. decurrens*, Klatt, Leopoldina, 23, 90. *Perimeniopsis perfoliata*, Sch. Bip., acc. to Klatt, l. c. *Tithonia scaberrima*, Benth. in Oerst., Vidensk. meddel., 1852, p. 91. *T. platylepis*, Sch. Bip., acc. to Benth. and Hook.f., l. c., 368 (name only). *Mirasolia scaberrima*, Benth. and Hook.f.

acc. to Hemsl., l. c., 168. — South Mexico, Mirador, *Liebmann*, no. 251; Chiapas, *Ghiesbreght*, no. 572, Caec. and Ed. Seler, no. 2187; Valley of Cordova, *Bourgeau*, no. 1851; Vera Cruz, *Pringle*, no. 6087; Orizaba, *Gray*; Guatemala, *von Tuerckheim*, no. 354 of Mr. J. Donnell Smith's sets; Costa Rica, *Pittier*, nos. 3136, 3735, *Tonduz*, no. 7196.

↔ ↔ Cuneately winged petioles tending to enlargement and usually auricled at the base.

37. *G. CALVA*, Gray. Shaggy-pubescent with long white silky hairs: habit as in *Tithonia*: leaves alternate, broadly ovate, acuminate, abruptly contracted to winged and (sometimes obsoletely) auriculate petioles: involucre hirsute. — Proc. Amer. acad., 19, 5; Hook. f. and Jacks., Ind. Kew., 1, 1076. *Tithonia calva*, Sch. Bip. in Seemann, l. c., 305. *Mirasolia calva*, Benth. and Hook. f., Gen., 2, 368; Hemsl., l. c., 168. Sierra Madre, Northern Mexico, *Seemann*, no. 2045; Durango, *Rose*, no. 2293.

var. lancifolia. Stem sparingly hirsute or villous: leaves lanceolate. — Tepic, Acaponeta, February, 1895, *F. H. Lamb*, no. 539. Types in herb. Gray and herb. U. S. nat. museum.

DOUBTFUL SPECIES.

G. CONNATA, Spreng., Syst. 3, 610 (*connatum*). — Branches hispid: leaves oblong, attenuate at either end, connate, hispidulous: peduncles terminal, short: foliaceous involucre subsimple. — Brazil, *Sello*. A species not mentioned in Martius, Fl. Bras., and probably not of this genus. The description is a translation of the original characterization.

G. MICROCEPHALA, Less. Herb with 3-nerved leaves, small cylindrical discoid short-pedicelled heads: leaves petiolate, opposite, paler beneath, oblong-ovate, long-acuminate, very obtuse at the base, sharply serrate, hirsute-hispid, scabrous, 3.1 to 5 cm. long, 1 to 3 cm. broad: scales of the involucre passing from flat semilanceolate foliaceous bracts, hirsute on the midnerve, to longer (about 4 mm. long) and broader dry linear shortly acuminate glabrous bracts, fimbriate-dentate at the apex, scarious on the margin, and traversed by green nerves: branches opposite, diverging at the apex into 3 short filiform branchlets bearing several heads (4 mm. long) above. — *Linnaea*, 5, 153, whence the foregoing description is

translated. — Near Hacienda de la Laguna, October, *Schiede* and *Deppe*; also Cordillera of Oaxaca, *Galeotti*, no. 2090 (acc. to Hemsl.). Exceptional in its discoid heads and perhaps not of this genus.

TRANSFERRED OR SUPPRESSED SPECIES.

G. DECURRENS, Klatt, Leopoldina, 23, 90, is *G. platylepis*, Gray, — an identity recognized by Dr. Klatt himself as shown by a manuscript note in his herbarium.

G. EHRENBURGIANA, Klatt, Leopoldina, 23, 90, is *G. patens*, Gray.

G. RUDIS, Gray (in Wats., Proc. Amer. acad., 22, 424) is *G. parkinsonii*, Hemsl., Biol. Cent.-Amer. Bot., 2, 163, — an identity kindly verified by Mr. Hemsley by comparison of the types.

G. SILVATICA, Klatt, Leopoldina, 25, 104 (1889); Bull. soc. bot. Belg., 31, 199 (1892). Representing this species in the Klatt herbarium we find two specimens collected by Lehmann at Cuenca, altitude 2,000 m., 16 October, 1879, Pittier's no. 6987, collected at San Rafael de Carthago, altitude 1,500 m., 28 August, 1892, and an excellent drawing of a specimen collected at Mt. Irazu, Costa Rica, by Dr. Hoffman. All of these appear to be identical and to agree in all more conspicuous characters with the original description. Nevertheless, careful dissections show that the ray-achenes are fertile and the ligules sessile indicating that the species is a *Heliopsis*.

G. TRILOBA, Gray, with fertile ray-flowers and an unequal scale-like pappus, is certainly a *Zaluzania*. The specific name *triloba* having been used in the latter genus the species may be transferred as *Z. grayiana*, n. comb.

G. TRIPLINERVIA, Klatt, in Engl. Jahrb., 8, 42 (not HBK.), is a *Heliopsis*, the ray-flowers being distinctly pistillate and fertile, while the ligules are sessile, not contracted into a slender tube at the base.

GYMNOPSIS VERBESINOIDES, DC. (Prodr., 5, 561) of the Island of Trinidad is an *Aspilia*.

GYMNOPSIS VULCANICA, Steetz in Seem. Bot. herald, 157, appears from the description and the examination of a single head to be *Gymnolomia costaricensis*, Benth.

2. SUPPLEMENTARY NOTES UPON CALEA, TRIDAX,
AND MIKANIA.

SOME years ago the writers (Proc. Amer. acad., 32, 1-30) published revisions of the genera *Calea*, *Tridax*, and *Mikania*. These synopses were based chiefly upon the representation of the genera in the Gray herbarium, and considerable difficulty was naturally experienced in the exact placing of some of the species of European writers whose types were not readily available for examination. The recent acquisition of the Klatt collection by the Gray herbarium does much to remove these difficulties and puts the writers in a position to add the following corrections and supplementary notes upon their former revision.

CALEA PEDUNCULARIS, var. *LONGIFOLIA*, Gray. Dr. Rose's no. 2730, from the Sierra de los Morones, near Plateado in the State of Zacatecas, corresponds closely with *Calea peduncularis*, var. *longifolia*, Gray, but has pappus, thus showing that the achenes of this variety are no more constant in regard to pappus than those of the more typical forms of the species. The variety is, however, readily distinguished by its long leaves.

C. PERFORATA, Klatt, Leopoldina, 20, 95, has immature heads but is otherwise like Fendler's no. 637 (from Tovar, Venezuela) which was relegated without question by Schultz Bipontinus to *C. solidaginea*, HBK. On comparing Dr. Klatt's type (coll. on the Mayquetea River by Edw. Otto, no. 459) with Kunth's description and plate (HBK., Nov. gen. et spec., 4, 295, t. 407) we can find no significant difference.

C. DENSIFLORA, Klatt, Leopoldina, 20, 96, is *Ageratum conyzoides*, L.

C. PELLUCIDINERVIA, Klatt, Bull. soc. bot. Belg., 31, 207, is not to be satisfactorily distinguished from *C. axillaris*, DC.

C. AXILLARIS, DC. To this species should also be referred *C. prunifolia*, Klatt, l. c., 208, in part (as to Pittier's nos. 3219, 3695, 4520, 4938, and 7023), not HBK. The distinctions between *C. axillaris* and its variety *urticaefolia* seem to be scarcely worthy of recognition.

C. pittieri sp. n. Shrub with slender flexuous terete puberulent or toward the end tomentulose branches: leaves ovate to elliptic, thickish, crenate-serrate, acutish, 4.5 to 7.5 cm. long, 2.5

to 3.7 cm. broad, rugose and very scabrous above, veiny grayish-tomentose and resinous-dotted beneath, 5-nerved from near the obtuse or subcordate base; petioles 6 to 9 mm. long, covered with a fine fuscous pubescence: heads numerous, rather small, discoid; pedicels filiform, 1 to 1.2 cm. long, some fascicled in the upper axils but most of them in regular hemispherical umbelliform leafy-bracted clusters (4 to 5 cm. in diameter) at the ends of the branches; involucre cylindric-ovoid, somewhat turbinate at the base, the outer scales very short, linear-oblong to narrowly ovate, herbaceous, tomentulose, the intermediate oblong, obtuse, often erose and squarrose at the tip, the inner lance-oblong, acute, bright yellow, petaloid: achenes narrowly fusiform, angled, 2.7 mm. long, callose at the base, covered with short spreading gray hairs; pappus-awns about 20, narrow, attenuate, 4.6 mm. long. — *C. prunifolia*, Klatt, Bull. soc. bot. Belg., 31, 208, in part, not HBK. — Costa Rica, banks of the Rio Ceibo near Buenos Ayres, altitude 200 m., January, 1892, *Prof. H. Pittier*, no. 4913, Chemin de la Caldera between San Mateo and San Ramon, *P. Bolly*, 25 January, 1892, no. 7015; also by *Prof. Pittier* in woods at Boruca, altitude 450 m., February, 1891. *C. prunifolia*, HBK., to which this plant was referred by Dr. Klatt, has larger leaves nearly or quite smooth and somewhat coriaceous. It also differs in the calyculate bractlets of the involucre, which are suborbicular and of larger size.

C. GRAYII, Klatt, Leopoldina, 20, 96, overlooked in our revision, should replace *C. tomentosa*, Gray, not Gardner.

C. TERNIFOLIA, Oliver, Trans. Linn. soc. ser. 2, 2, 277, t. 43, figs. 9-16 (1886). For this species the name of which is antedated by *C. ternifolia*, HBK., Nov. gen. et spec., 4, 294, we would propose *C. oliverii*.

TRIDAX GALEOTTII, Klatt, l. c., at least as to the plant with lobed pilose leaves. *T. tuberosa*, Rob. and Greenm., Proc. Amer. acad., 32, 4. In the Klatt herbarium *T. galeottii* is represented by two sheets of well executed drawings. On one is an excellent representation of the plant we have called *T. tuberosa*, with lobed leaves, cuneate at the base and distinctly hirsute. On the other sheet two plants are represented, one being identical with that just mentioned, the other having the more oval serrate unlobed leaves of *T. brachylepis*, Hemsl. Dr. Klatt's description clearly shows that he had in mind the plant with lobed leaves. The description, however, is quite in error as to the involucral scales being 2-seriate. They are clearly

3-4-seriate in both his drawings and in a single authentic head preserved in a pocket on one of the sheets of drawings. In the arrangement of species *T. guleottii* should, accordingly, be inserted where *T. tuberosa* has been placed.

T. IMBRICATA, Sch. Bip. in Klatt, Flora, 1885, p. 202. *T. petrophila*, Rob. and Greenm. l. c., 5. The authentic specimen of *T. imbricata* in the Klatt herbarium is very poor, but sufficient to show with a fair degree of certainty the identity of *T. petrophila*. The involucre is here also 3-4-seriate, not biseriate as we had supposed.

T. VERTICILLATA, Klatt, Leopoldina, 25, 107 (1889). This South American species, omitted from our revision, is the only member of the genus with verticillate leaves. In the arrangement of the species it may well be placed in subgenus *Eutridax* after *T. angustifolia*.

T. EHRENBERGII, Sch. Bip. in Klatt, l. c. Klatt's drawing of this species shows a plant with long internodes and habit of *T. dubia*, but the achenes preserved in the Klatt herbarium have the pappus rather of a *Calea* than a *Tridax*. The species must remain doubtful until more complete material can be seen.

MIKANIA OLIVACEA, Klatt, Bull. soc. bot. Belg., 31, 195. — An examination of the type in the Klatt herbarium shows it to be Pittier's no. 4933, not 4433, as cited in the original publication of the species.

M. PUNCTATA, Klatt, l. c., originally described as having the heads 7-flowered, proves, on careful dissections of portions of the type material, to have uniformly 4 flowers in each head, fully agreeing in this regard with the other species of the genus.

M. FENDLERI, Klatt, Abh. naturf. gesellsch. Halle, 15, 324, although reduced in our revision to a synonym of *M. cordifolia*, Willd., is probably worthy of specific rank.

M. gonzalezii, sp. n. Vigorous smoothish twiner: branches obsoletely 6-angled, finely striate, glabrous: leaves large, thin, glabrous, ovate, entire, acute, broadly and shallowly cordate or subcordate, 5-nerved from the base, 4 to 12 cm. long, 3 to 10 cm. broad; petioles 1.5 to 5 cm. long: heads in an elongated open panicle with short opposite corymbiferous branches (5 to 15 cm. long); bracts of the inflorescence oblong-lanceolate, petiolate; involucre 7 mm. long, subtended by shorter sessile oblong-elliptic or oval bractlets; pedicels puberulent under a lens; involucre

scales oblong, essentially glabrous except at the obtusish or barely acute tip: corolla 5 to 6 mm. long, about equalling the sordid pappus: achenes 4 mm. long, nearly glabrous. — Collected by *Prof. C. Conzatti* at Colonia Melchor Ocampo, Vera Cruz, Mexico, altitude 1,200 m., 8 December, 1895, no. 18, and by *Prof. C. Conzatti*, and *V. González* in Canton de Cordoba, Vera Cruz, 27 December, 1897, no. 637 in part. This noteworthy plant is clearly distinct from any Mexican species known to us, nor have we been successful in referring it to any South American species. In the genus it should, probably, be placed near *M. cordifolia*, from which, however, it differs in the size, form, texture, and glabrous character of the leaves, which are more or less nigrescent in drying. We take pleasure in dedicating the species to Mr. V. González, who as the able assistant of Professor Conzatti, has done much to further the knowledge of Mexican plants.

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No. 6. — *The Development of Penilia schmackeri* Richard.

By MERVIN T. SUDLER, BALTIMORE, MD.

With three plates.

During June, 1896, immense swarms of small crustaceans suddenly appeared in the water of the harbor of Beaufort, N. C. Their numbers were so great that the animals usually found near the surface of the water were completely obscured and, in towing, the meshes of the net after being drawn through the water a few yards were clogged with these crustaceans. This abundance lasted but a few days when the creatures disappeared completely and as suddenly as they had appeared. Dr. C. P. Sigerfoos, then of the marine laboratory of the Johns Hopkins university, preserved a number for future study.

Three methods were used to preserve and fix these animals; viz. :—

1. A saturated solution of corrosive sublimate used cold for a few minutes.
2. A corrosive sublimate and acetic acid reagent, composed of
Corrosive sublimate (saturated solution) . . . 90 parts
Glacial acetic acid 10 “
3. 80% alcoholic picro-sulphuric acid.

The animals were washed in water after treatment with each of these solutions, run up through the graded series of alcohol until they were in 80%, and kept until used. The material so preserved was placed in my hands and was studied by means of sections of the adults containing young and the separate embryos after they had been removed and by means of adults and embryos mounted whole. Kleinenberg's haematoxylin as a staining agent gave the best results in the first case, and where they were mounted whole a few moments staining in Czokor's alum cochineal proved the most satisfactory. Xylol was used as a clearing agent and Canada balsam as a mounting medium.

SYSTEMATIC POSITION.

The crustaceans were found to be Cladocera (Daphnoidea) and belong to *Penilia*, of which two species have been described by

Dana. All of the members of the Sididae thus far known are marine and especially distinguished from all other families of the Cladocera by the presence of six pairs of thoracic appendages and by the fact that one or both of the branches of the second antennae have less than three joints, the characteristic number for most of the members of this group. The species has been determined by Prof. E. A. Birge of Madison, Wis., who has compared the form with the type specimens of M. Richard.

The embryology of no member of the Sididae has been studied, and most of the work on the entire group has been of a systematic or anatomical character. Only three papers of importance dealing with the embryology of the Cladocera are known to me; these are by Grobben ('79), Lebedinsky ('91), and Samassa ('93).

Other articles, such as those of Dohrn ('69) and of Zaddach ('41), are old and give but few details of development.

ANATOMY.

Penilia when alive is transparent and has no pigment of any kind except the very small amount in its single median eye. It measures from 0.8 to 1.0 mm. in length, not including the biramose swimming antennae, which with their setae are about 0.8 mm. The long pair of abdominal setae are 0.4 mm. in length, making the entire animal from 2.0 to 2.2 mm. long. In general shape (Fig. 1) it somewhat resembles *Daphnia similis* (Claus). At one stage of the life of *Penilia* eleven pairs of appendages appear, but in the adult ten only are present. The small anterior, or first, antennae are situated on the posterior side of the two prominent horns which project downward from either side of the head. They contain nerve cells, and one long sensory seta is attached to the anterior side of their distal end and to the posterior side a pencil of small sensory hairs. The large biramose swimming antenna is composed of one large basal joint from which extend an exopodite and endopodite, each composed of two segments, the first about three times as long as the second joint. These joints have long, stiff setae to aid in swimming. The mandible is strongly developed and moved by comparatively large muscles. The first maxilla is composed of a single joint. It is situated directly behind the mandible and is much weaker than that appendage. It possesses setae on its end.

The second maxilla disappears quite early in the life history of the animal, and takes no part in the anatomy of the adult. The six pairs of thoracic appendages are all much alike and are all biramous.

The heart is oval in shape and lies above the intestine just in front of the brood-chamber and directly over the shell-gland. It is composed of about thirty cells and has one pair of ostia situated near the posterior end of the organ.

The digestive tract has no digestive pouch or gland, but a number of gland cells around the pharynx may to some extent take its place by secreting similar substances. The intestine curves over against the dorsal side of the animal and terminates at the anus between two long setae. The shell-glands are nearly round and are composed of from six to twelve large cells surrounding a central lumen. This lumen empties to the exterior in the angle formed by the shell and the body of the animal. The shape of these glands in *Penilia* is unlike that of any other crustacean. In their histological structure the cells show an outer striated deeper staining border and an inner striated but lighter staining portion. The nuclei stain very dark. These cells resemble in structure the secreting cells of the homologous glands of *Astacus fluviatilis* figured by Grobben, but they are much larger. This comparison must not be carried too far as the proportion between the different staining portions is not alike. Ordinarily phyllopods show only striated cells, both borders being very much alike.

The ovaries are paired and lie on either side of the digestive tract near the posterior end of the animal. They do not exhibit the cells arranged in groups of four as Claus describes for *Daphnia magna* or Weismann for *Leptodora hyalina*, but the eggs are in all probability formed in the same manner, *i. e.* from four cells. The absorption and coalescence of the four into one must be quite rapid as transition stages are hard to find.

The brood-chamber lies above and to either side of the digestive tract. In cross-section it is heart-shaped with the apex of the heart up toward the dorsal side and the depression at the larger end of the heart being occupied by the intestine. Its size varies greatly, depending upon the number and size of the embryos it may contain.

No males were found among the many hundreds of specimens that I have examined.

THE DEVELOPMENT OF THE EGGS.

The eggs of *Penilia* when laid are oval and much longer than broad, measuring from 100 or 110 μ in length and 20 or 30 μ in breadth. Usually from four to six are deposited at one time, although the number may range from one in young or small animals to eight in large well-developed adults. Generally the same number is laid on either side but exceptions to this are found. According to Grobben the brood-chamber of *Moina rectirostris* may contain twenty-two eggs, and he has seen as many as thirty well-developed embryos in that of *Moina paradoxa*.

The egg of *Penilia* contains but little yolk and possesses a small deep staining nucleus surrounded by a circle of clearer protoplasm. They have a vitelline membrane and never at any stage do they possess more than the one. Lebedinsky found two in *Daphnia similis*, a chorion and vitelline membrane. Grobben always found but the one (vitelline) in *Moina*. I think the egg of *Penilia* represents the surviving cell of four homologous cells, and for these reasons. The ovary is usually seen to be made up of cells arranged in quite a definite manner. At the posterior end the cells are of different sizes and arranged in no regular order. This is the germinal epithelium. At the anterior part a row of cells alike in size and appearance occurs. These, however, are not arranged in sets of four so as to give the whole a bead-like structure, as is seen in *Daphnia* and *Leptodora*, but they are always some multiple of four. As the usual number of eggs found on a side is three, so the usual number of cells seen in ripening ovaries is found to be twelve. The smallest number of these cells when any at all are present is four. The size of these four cells is slightly larger than that of the mature egg; but the size of the egg corresponds very nearly to the size of them all, and is therefore very much larger than any one cell. In a few (three) specimens I have seen what I have taken to be the act of fusion. Nuclei in partially broken states occurred in protoplasm which seemed separated in places and slightly broken and irregular. This fusion of the four cells must occur quite rapidly as transition stages are so rare. In some cases, in eggs which had not segmented, small fragments of material which stained as nuclear material appeared. These were embedded in the substance of the egg, and I interpreted them as fragments of the nuclei of the three cells that lose their identity in the formation of the egg. I found

nothing that I could call a polar-body. This structure is present in *Daphnia similis* until the eight-celled stage according to Lebedinsky and the sixteen-cell stage in *Moina* according to Grobben. These observers did not see the formation of the polar-body, but state that it is formed while the egg is in the ovary. From these descriptions it seems to me that there is a possibility of its not being a polar-body but a disintegrating nucleus of one of the ovarian cells which has entered into the composition of the egg.

THE POSITION OF THE EGG IN THE BROOD-CHAMBER.

The eggs when laid lie in the brood-chamber with their long axes parallel to that of the mother where not more than two are laid on either side. In large individuals the orientation may be the same with a larger number of eggs; but in most cases where the number on a side is more than two, the eggs overlap so that the posterior end of each egg is outside the anterior end of the egg directly behind it. In some cases this position is not assumed until cleavage has advanced to the four- or eight-cell stage, and in a few cases it may not be assumed until the appearance of the appendages. Later on the change in position is controlled by different factors, such as the change in the shape of the embryo and the change in the shape of the enlarging brood-chamber. These will be described later.

The embryo is nourished by means of the blood-plasma or albumen with which it is surrounded. Its increase in size is due entirely to material obtained in this way. In the preserved specimens this nourishing substance has coagulated and causes the embryos to adhere quite firmly to the mother. In sections showing a segmentation cavity we find a coagulum slightly stained which probably comes from the same source.

SEGMENTATION.

The first cleavage plane is transverse to the long axis of the egg and divides it into two separate and distinct cells, the anterior of which is slightly larger than the posterior. (Fig. 7.)

The next plane of division is through the long axis of the egg at right angles to the first and is almost parallel with a plane passing through the middle line of the adult. A four-celled embryo is thus formed with the two anterior cells slightly larger than the two posterior ones. (Fig. 8.)

Sections of eggs throughout their development show through the protoplasm a sharply defined and delicate reticulum with coarse meshes. In the young stages and with high magnification, small enlargements can be distinguished where the threads meet to form the meshes.

The third plane of division is longitudinal but perpendicular to the second, forming an eight-celled embryo in which the cells of the anterior end are still slightly larger than those of the posterior end. (Fig. 9.)

In the fourth stage of cleavage the eight cells have divided transversely making sixteen cells. (Fig. 10.) Two planes of division were necessary to cause this. The eight anterior cells can still be seen to be a very little larger than the eight posterior ones. At this stage Grobben has already distinguished a cell as the mother-cell of the genital organs, another as the primitive entoderm cell and still others surrounding the "genitalzelle" which are thought to give rise to the mesoderm. Thus at this early stage these few cells foreshadow all of the germ layers as well as the sexual cells of the adult. These cells are distinguished 1st by their peculiar staining properties and 2d by differences in their action; *i. e.* time of division in reference to the other cells of the egg. Samassa in his studies on the same animal finds the so-called "Grobben'sche zelle" ("genitalzelle" of Grobben) and the entoderm present but not distinguishable to the same extent as Grobben claims. He is unable to distinguish the "Grobben'sche zelle" after the original one has divided into eight. He fails to find that it develops into any particular organ of the adult. In *Penilia* I can find no cell marked from its fellows by any peculiarity at this stage. The cells vary somewhat as to size but apparently not in such a definite manner as on that account to allow any particular one to be chosen and its history followed.

In the fifth or thirty-two-celled stage regularity of cleavage planes is hard to observe and probably does not occur with exactness. From the arrangement of the cells, however, the planes must be longitudinal again in their general direction. It is no longer possible to distinguish any difference in the size of the cells lying at the anterior end from those at the posterior. A cross-section of this stage shows segmentation to be complete with a large segmentation cavity containing no yolk. (Fig. 11.)

The sixth or sixty-four-celled stage still shows no sign of differen-

tiation. All of the planes of division cease to be distinguishable as such from this time. (Fig. 12.)

The seventh stage probably has about one hundred and twenty-eight cells and shows the beginning of gastrulation. (Fig. 13.)

GASTRULATION.

This process always takes place in a very definite part of the egg with reference to its position in the mother.

No matter on which side of the intestine of the adult the egg lies, gastrulation always occurs at its outer posterior corner. An exception to this rule was not observed in the scores of specimens examined at this stage. A median horizontal longitudinal section (Fig. 12) at this time shows projecting into the segmentation cavity from the outer and posterior angle of the outer wall of the egg an indefinite amount of protoplasm containing one or two nuclei. At the particular point to which this is attached to the outer wall one or rarely two cells have sunk below the surface and are in the process of migrating into the interior. (Fig. 13.) The nuclei and protoplasm shown in the interior have reached this position by a similar process. In all probability regularity in the planes of division has disappeared even before this time, but it certainly has now. The cells, however, continue to divide at nearly the same time. An older embryo (Fig. 14) shows that both the amount of protoplasm and number of nuclei in it in the segmentation cavity have increased and a larger number of cells are concerned in the inwandering and formation of the mouth of the gastrula.

In *Moina*, gastrulation begins later than in *Penilia*, and apparently the process is more rapid since more cells are concerned from the beginning. In an older *Penilia* larva this indefinite protoplasmic mass has become quite a definite rod running through the segmentation cavity and contains numerous nuclei. The gastrula mouth is much deeper and enlarged. No differentiation except that noted can be seen. Cell walls are now made out with great difficulty, if at all, although the individual cells stand out as such very plainly. Boundaries between them are marked off by lighter staining areas of protoplasm. (Fig. 15.) At a corresponding or even earlier stage, *Moina*, according to Grobben, already shows the beginning

of the nervous system. Samassa states that the embryo is more advanced before such a differentiation can be distinguished.

SIZE OF EMBRYOS.

So far in *Penilia* the embryos have grown but little, the elements composing them simply becoming smaller with each succeeding stage; but from this time on, increase in size of the whole is marked and rapid. In this respect it agrees with the development of *Moina*. The embryos and eggs from the same mother are all of the same size and stage, as far as can be detected, throughout their development. Embryos of like stages but from different mothers vary somewhat in size; a younger stage is larger than a more advanced one from another animal. Grobben found the same difference in size present in the embryos of *Moina* and thought the cause was traceable to variation in the size of the eggs when first laid by the different mothers. This furnishes a partial explanation for the phenomena seen in *Penilia* as the early segmentation stages of this animal show the same differences in size, but never to the same extent that the older embryos do. The amount and rapidity with which the nutritive blood-plasma is supplied to the embryos also vary in all probability, and this may be the principal cause in the greater variation in size seen in the older embryos.

THE GERM LAYERS.

The protoplasmic rod occupying the segmentation cavity is composed almost entirely of the entoderm. The mesoderm originates on either side of the mid-ventral line at the angles of the gastrula, which at these particular points cannot be separated definitely into entoderm and mesoderm. Certain cells, instead of growing up into the center of the segmentation cavity, project out into these angles and toward the ectoderm. As they multiply they increase in length and width, but are only one-layered in thickness. They leave the entoderm completely and cling to the inside of the ectoderm. (Fig. 16.) These and their descendants form the mesoderm of the adult animal. Samassa finds on the ventral side of *Moina* a mass of tissue somewhat semilunar in cross-section. The central-lying cells form themselves into a solid cylindrical row. These are the ento-

derm, and the rest to either side of them are mesoderm. As has been shown, the separation in Penilia is much earlier. The facts observed in Penilia correspond to those given by Lebedinsky for *Daphnia similis*, where the mesoderm spreads forward as two symmetrical rows from the gastrula invagination. At a later stage in Penilia (Figs. 17-23) the mesoderm has grown slowly forward and together at the mid-ventral line, making the outer wall two-layered with the exception of the dorsal side where only ectoderm exists.

The gastrula mouth gradually becomes smaller, and by the time the second antennae show it has disappeared almost completely, leaving its position marked only by the entodermal rod, which soon breaks away, making it impossible to locate the spot where the anus breaks through. Grobben concludes that the mouth of the adult Moina arises directly from the gastrula mouth of the larva. This derivation of the mouth is impossible in Penilia, as will be seen later. In fact, it is the rule throughout the Crustacea for the anus and not the mouth to be formed from or near the position occupied by the gastrula mouth.

The derivation of the anus in Penilia is open to question. The anus appears in the middle line and in the same or immediate vicinity as that occupied before by the gastrula mouth. The anus may be formed *de novo* slightly above or below this point. The gastrula mouth completely disappears, and so it is impossible to say whether it ever reopens.

THE APPENDAGES AND CHANGE IN THE POSITION OF THE EMBRYOS.

About this time a change in the outward form of the embryos makes itself apparent. The gastrula mouth still lies at the posterior and outer angle of each egg in reference to the mother and in the middle line in reference to the embryo. The anterior end flattens itself very slightly dorso-ventrally and becomes broader than the posterior. Two pairs of prominences appear anteriorly; the anterior of which are very small and weakly developed, frequently nothing more than the smallest angles on this end of the embryo. The more posterior and larger are more sharply pronounced. They project backwards on either side from the anterior flattened area and make the flattening effect much more pronounced. Both pairs of these prominences lie in a plane perpendicular to one cutting the

gastrula mouth and making the embryo bilaterally symmetrical. The first pair of these prominences become the first or sensory antennae, while the second will be the chief locomotor organ of the adult, the second or swimming antennae.

Up to this time the position of the embryos has been practically the same and only a very slight change has occurred from that first noticed in the segmenting eggs. The embryos have elongated, and that is all. As the appendages appear the change in shape of the embryos and of the enlarging brood-chamber causes a shifting in position of the embryo with reference to the mother.

Upon looking at the cross-section of an adult with a brood-chamber as previously described it is seen to be heart-shaped with the apex upwards at the dorsal wall and the intestine occupying the depression in the blunt end of the heart.

Before any change in the outward shape of the embryos occurs they lie for the most part in the concavity on either side of the intestine with the posterior ends of the ones in front to the outside and somewhat beneath the anterior ends of the embryos directly behind. When the appendages push out the flattening at the anterior end occurs, and a resistance is encountered on either side by growing against the outer walls of the brood-chamber externally and against the wall of the intestine internally. The outer antennae strike the wall at an angle so that an increase in width causes the edge of the embryo to rise and revolve slightly on its other antenna, as an axis, in such a way as to cause the region once occupied by the gastrula mouth to look dorsally and outward instead of outward with a slight ventral tendency. An exception to this sometimes occurs in the case of the most anterior embryos which do not have the other factor; *i. e.* the posterior end of another embryo under the outer side of its anterior end and changing its position. These embryos in some cases may assume such a position that the angle formed by the antenna and the outer wall of the animal is in the opposite direction from the rest. This causes a rotation in the other direction so the position once occupied by the gastrula mouth is downward and in, instead of upward and out, as in the rest of the embryos. This opposite rotation seems to affect only the most anterior embryo and even in this case it is the exception and not the rule. The normal or usual position assumed by these anterior embryos is not exactly like that taken by the rest in the brood-chamber but one in which the ven-

tral surface is farther away from the mid-line and more toward the side. Thus it is possible to distinguish almost exactly the comparative importance of the two mechanical factors most concerned in the revolution.

The embryos now increase in length so that the posterior end of each embryo lies still further back and to the outside of the anterior end of the embryo just behind it. The height of the brood-chamber increases, and still further growth and flattening of the embryo caused by the enlargement of the second antennae tend to raise the anterior of each embryo above the intestine and allow the smaller rounded end to drop so that it now lies to the outside and beneath the anterior end of the embryo immediately behind it. This constantly increasing factor adds to the rotation until it may cause the side which was originally next to the outer wall to lie on top of the intestine. With the increase in size in all directions the embryos become very much crowded in comparison with their condition at first. The brood-chamber also enlarges, and the floor is raised until it is on a level with the intestine. A cross-section of it now shows it to be hemispherical in shape rather than heart-shaped. The embryos now lie almost wholly above the intestine and have lost to some extent the slant in the dorso-ventral plane. The crowding occasioned upon the maturity of the embryos causes many changes of an irregular nature in their positions, so that they depart from the positions described, especially in regard to the ventral side being uppermost or directly dorsal. In nearly mature embryos, however, their long axes are more nearly parallel with that of the mother than before. The position of the embryos of *Penilia* is thus seen to be a changing one in the different stages of their development. To a certain extent, the degree to which the embryos are shifted depends upon their age, but throughout their development the anterior end of the embryo lies toward the corresponding end of the mother. In older stages, the ventral side is uppermost and looks toward the side, except as noted, where it is just the opposite, looking downward and toward the intestine of the mother. While the axis of the embryo is never exactly parallel to that of the mother, in a general way it always lies in the same direction, sufficiently so to see with perfect clearness that the egg is oriented and that as it develops its position in regard to the mother is changed by a series of mechanical factors resulting from the growth and the enlarging brood-chamber to accommodate its increasing contents.

THE APPENDAGES.

The order of the appearance of the appendages of *Penilia* departs from the usual rule for Crustacea. The first or sensory antennae do not appear first but only after the second antennae are clearly distinguishable, and in some cases where the retardation is exceptional, they may not appear sharply differentiated until the second antennae, mandibles, and maxillary region are plainly formed. A maxillary region is differentiated before the thoracic appendages appear and the appendages themselves do not develop until rudiments of every other appendage of the entire animal are developed. The thoracic appendages appear in the usual order, as the most anterior is the oldest and those following show a perfect gradation in their development. The appendages will be taken up in the order of their position and not in reference to the time of their appearance.

FIRST ANTENNAE.

The first or sensory antennae, as has been just said, vary considerably as to the time of their appearance. They begin as angles on either side of the rounded anterior end of the larvae. They may appear in this way when the second antennae are just beginning to be plainly visible or they may not appear until the mandibles and maxillary region are marked off. This angle increases in prominence until it gradually forms a rounded lump projecting anteriorly, its connection with the body of the embryo being the smallest part of its diameter. (Fig. 28.) Its relation to the entire animal is shifted as the bending of the head and the outgrowth of the upper lip occur. From its extreme anterior position in front of the second antennae it changes to the ventral side of the embryo, and finally in the older embryos and adult its position is ventral and posterior to that occupied by the second antennae. The first antennae project on either side from outgrowths or horn-like processes developed from a part of the upper lip. They remain small throughout life and in the adult consist of but a single joint with nerve-cells and sensory fibers or setae.

THE SECOND ANTENNAE.

One of the first changes noticed in the outward shape of the embryo is a widening of the anterior third and the appearance of two rounded prominences projecting posteriorly on either side of this area which will form the second antennae of the adult. These two projections grow backward rapidly and, at a stage when the maxillary region and two thoracic segments are present, bifurcate. Their position in regard to the entire animal shifts, approaching more and more the anterior end of the embryo as the head bends and in the adult coming to occupy the extreme anterior dorsal corner of the animal. From their first appearance the second antennae are the most prominent appendages. They grow rapidly and appear first and thus foreshadow their great importance in the adult. The swimming hairs do not begin to show until just before the embryos are mature. The second antennae are folded back close to the side of the embryo as long as they are in the brood-chamber of the mother.

THE MANDIBLES.

The mandibles are the next appendages to appear and the time when they are first recognizable varies but little. At a stage represented by Fig. 21, when the second antennae are well defined as two processes projecting posteriorly, the mandibles show as paired outgrowths just posterior and ventral to the second antennae. These eminences do not project either posteriorly or anteriorly but directly outward from the middle line. As the embryo grows older they assume an upright position (project ventrally) and approach more and more the middle line. In the adult they meet in the middle line. They are stout, serrated on their distal borders, and moved by well-developed muscles. (Fig. 1.) Except for the change in position in the direction in which the appendages point, there is no shifting such as one sees in the case of the two previous appendages described. Their position in the adult is practically that occupied by them throughout the embryonic development.

THE MAXILLAE.

A maxillary region is differentiated immediately after the mandibles are well formed, and upon this the appendages appear later. The first pair of maxillae appear first and the second pair follow shortly. The first are the largest and show themselves as two small rounded eminences projecting at first away from the middle line but closer to it than the mandibles. Their position as development proceeds changes but little, except that the appendages of the adult point more toward the middle line. They are small even in the adult and consist of but a single joint bearing setae on its terminal extremity. The second maxillae develop at first as small thickenings which increase until the appendages are small projections, reaching their maximum development in a stage represented by Fig. 27, when the thoracic appendages are just beginning to show the first trace of bifurcation. These appendages disappear as rapidly as they come, and by the time the bifurcation of the thoracic appendages is well marked they have become reduced to mere darker staining masses which soon cease to be recognizable as appendages. The second maxillae are formed sooner in *Penilia* than in *Moina*, where they appear after the thoracic appendages have already bifurcated. They persist, however, much longer in *Moina*, disappearing only just before the larvae are set free. They are much more transient in *Penilia* and never so well marked.

THE THORACIC APPENDAGES.

The thoracic appendages follow the usual rule and appear in a regular sequence of order making the anterior the oldest and the posterior the youngest. The thoracic region becomes divided into six segments in the same order. Furrows running from the ventral side up to the dorsal side appear. These cause the prominences between them to become more pronounced as development proceeds. This condition causes the peculiar fluted appearance presented by the embryo in side view as seen in Fig. 26. These prominences approach much closer to the middle line on the dorsal than on the ventral side. A view of the embryo at this stage shows the prominences projecting slightly beyond the ventral surface and squarish in outline. This

portion represents the beginning of the thoracic appendages. Near the center of these squarish limb-rudiments which represent the basopodite a portion becomes more prominent, projecting directly downward. This eminence is the beginning of the endopodite and first shows itself in the most anterior thoracic appendage, although the difference in the time of their development is not so marked as that of the first appearance of the thoracic segmentation. The endopodite grows ventralwards until we have it standing nearly at right angles with the exopodite. The free ends of these bend more toward the mid-line as they grow older and the shell grows back covering them. All of the thoracic appendages are bifurcated in the adult. The third of the series of thoracic appendages becomes the largest in the adult and they grade off from it smaller in either direction. The sixth or last pair is the smallest but preserves the structure typical of them all.

The presence of six pairs of thoracic appendages is the chief distinction of the genus *Penilia*, and Claus states in reference to the presence of six thoracic appendages in a larva of *Leptodora hyalina* that we must consider this to be the original number for the Cladocera.

THE SHELL.

The shell of *Penilia* appears as a lobed fold of ectoderm on either side just above the maxillary region at a stage intermediate between those shown in Figs. 1, 5, 28. The integument here rises up into a fold projecting posteriorly. This fold is lobed, as seen from a dorsal view, with the apex of the angular area dividing the two shell-rudiments directed toward the head of the embryo. This is shown by the most anterior embryo of Fig. 1. On either side this fold runs well down to the ventral surface. Seen from the ventral side when young, it resembles an appendage to a considerable extent, since it is about the same width and composed of two layers of cells and lies in the same general position as that assumed by a thoracic appendage. These saddle-folds grow back gradually on either side, covering the body and appendages as we have it in the adult. The rate of growth and shapes can be seen in Figs. 1, 5, 6, 28, and 29.

THE NERVOUS SYSTEM.

The nervous system of *Penilia* is composed of a supraesophageal ganglion and a series of ventral ganglia, but the supraesophageal and its commissures contain most of the nervous material of the adult. As the most important part of the nervous system, it is the first to develop. At a stage when the second antennae are plainly seen, represented by Fig. 20, the ectoderm is found to possess several layers on either side of the mid-line and at the anterior extremity of the embryo. These paired enlargements or accumulations of cells are the first beginning of the supraesophageal ganglion. The cells that compose them have no distinct walls, but in some sections appear almost circular, except where pressed against one another. The cytoplasm is light staining and the nuclei are very distinct. According to Samassa, the supraesophageal ganglion of *Moina* arises from paired rudiments in the same position as described for *Penilia*, but earlier in its development. Grobben found in *Moina* that at first the rudiment of the supraesophageal ganglion was single, but afterwards became paired. He found this unpaired rudiment to appear even earlier than Samassa, and the latter says in regard to this that Grobben was mistaken in the stage of his embryos in which he first found it.

The ventral chain of ganglia also rise from paired thickenings of ectoderm. These appear externally as two slight ridges on either side of a groove, running down the mid-line on the ventral side of the embryo just anterior to the stomodaeum to the abdominal part of the embryo. Grobben calls this groove the "primitivfurche" in *Moina*. At a stage represented by Fig. 29, the cells composing these two folds have separated themselves into nine groups, which can be seen in longitudinal sections. The third one from the anterior end of the group is the smallest and least well marked. This is the ganglion of the second maxillar segment, and probably fuses with the one just anterior to it, as Grobben describes for *Moina*. This condition corresponds almost exactly with the figure given by Grobben for *Moina*, except in that case only eight ganglia are present, which is what we should expect, *Moina* having one pair less of thoracic appendages. The supraesophageal commissure is seen in sections as a more or less definite string of cells running up to one side of the digestive tract. In the adult a cross-section

of the ventral nerve cord reveals a section shaped somewhat like a dumb-bell, showing that while the ganglia unite they do not entirely lose their double character.

THE EYE.

The eye of the adult *Penilia* is quite small in comparison to that of other *Cladocera*. Its development and separation from the brain rudiment do not take place until quite late. The rudiments of the eye of *Penilia* do not arise separately or around distinct centers, but they are plainly seen to be lobed and paired to that extent.

THE DIGESTIVE TRACT.

The beginning of the mid-gut of *Penilia* is seen when the inwandering of cells occurs at gastrulation. The rod of tissue thus formed breaks away or very nearly so from the ectoderm, but retains its general position in the long axis of the embryo. The rod is solid, but is not regular in outline or cylindrical at first. See Figs. 15, 16, 17, 30, 31, and 32. Later this indefinite rod assumes definiteness, and at a stage shown in Fig. 26 the mid-gut shows as a clearly defined cylindrical rod arranged radially. Later when the embryo enlarges and begins to assume the adult form, as at a stage represented by Fig. 28, the lumen appears. The mouth and pharynx are formed from an inpitting which occurs just under the rapidly elongating upper lip. The origin of the anus is also from an inpitting of the ectoderm at the opposite end of the embryo. Whether this inpitting occurs at the same spot at which gastrulation occurred or whether it is entirely new, I am unable to state definitely, but, judging from the position of the gastrula mouth when the embryo is revolved, I think the anus is formed dorsal to it. The anus forms in *Penilia* directly in the center of the posterior end and in the mid-line, while the position of the gastrula mouth when the embryo is revolved is in the mid-line but considerably ventral to the center of the posterior end. Grobben finds the anus of *Moina* arising at the posterior dorsal angle of the embryo. He also finds that the mouth and anus appear earlier in *Moina* than in *Penilia*.

According to Samassa we do not have an entodermal rod as dis-

tinct in *Moina* as in *Penilia* but more or less mixed with the mesoderm. Only later the central cells of this mes-entoderm separate themselves from the main mass to form a cylindrical and solid rod of entoderm which later obtains a lumen as described for *Penilia*. The cells lying outside of this are the mesoderm.

THE SHELL-GLAND.

The shell-gland of the adult *Penilia* is a marked departure from that organ as seen in other members of the group. Instead of being long, tubular, and coiled, it is almost circular in outline. It is composed of from six to ten large cells described elsewhere. The shell-gland has its origin in the mesoderm in *Penilia*. Certain cells in the mesoderm on either side of the digestive tract just above the second maxillary segment begin to enlarge. These cells have larger, darker staining nuclei than the surrounding mesoderm cells, and they soon show a spherical arrangement. These cells continue to enlarge until they form a solid sphere almost as large as the organ of the mature animal but with no lumen present. Later, but before they have assumed the definite histological structure of the adult, they appear around a lumen with an opening to the exterior through the ectoderm. Grobben also confirms the mesodermal origin of this gland for *Moina*, but the different shape and histological character of the glands of the adults make their rudiments in the respective embryos somewhat different. Kingsley finds the homologous gland of *Crangon* to be of mesodermal origin and that later in the development it acquires an ectodermal opening to the exterior. Reichenbach in his work upon *Astacus* and Ishikawa in his work on *Atyephira* both find this gland of ectodermal origin and the mesoderm plays no part in any stage of its development.

THE CERVICAL GLAND.

Throughout the arthropods one or more glands are formed in the neck and head region at various stages in their development. Different investigators have given the same structure different names such as cervical gland, neck-organ, dorsal gland, and endusium. In *Penilia* a cervical gland is present here in the

embryo but disappears before the animal is born leaving no trace of its existence in the adult. In a Penilia embryo at a stage represented by Fig. 28 it shows its maximum development which is quite weak in comparison with other members of the Cladocera. At the stage referred to, it is composed of from fifteen to twenty cells, each of which is longer than broad and larger at the distal end than at the surface end. The whole organ is shaped somewhat like a truncated cone with a small depression at the smallest end where it comes to the surface. (Fig. 33.) It is situated in the middle line at the anterior dorsal angle of the embryo. Its position in Penilia is more anterior than in Moina. It appears about the same time in embryos of both animals but disappears much sooner in Penilia than in Moina, in which it is much stronger developed than in the former.

THE OVARY.

The ovary of Penilia is of mesodermal origin. I have failed completely to find a genital cell from which the future genital organs originate. I have been unable also to distinguish any particular cell corresponding to the "Grobben'sche zelle" of Samassa. Lebedinsky and Samassa both agree with me in being unable to find any trace of a differentiation of any kind at such an early stage to form the genital organs. In Penilia certain mesodermal cells lying to either side of the intestine become larger and their cytoplasm stains clearer than those surrounding them. These form a row in a position occupied by the ovary in the adult. Samassa finds the ovaries of Moina derived from four mesodermal cells, two on either side. These cells multiply and grow backward to form the ovary. In Penilia the origin of the ovary corresponds more closely to the origin of the same organ in Branchipus. According to Claus it originates here as paired rudiments lying in rows on either side of the digestive tract.

THE HEART.

The heart of the adult Penilia is an oval-shaped body composed of about thirty semilunar shaped cells. It possesses a single pair of ostia situated toward the posterior end. The heart arises in the

mesoderm in a position in the embryo corresponding to that occupied by it in the adult. Two lots of cells, one on either side of the middle line and above the intestine, become longer and tend to meet in a mid-dorsal position. These gradually become longer and more curved. These ends meet in the middle line and the structure of the heart is practically complete as seen in the adult (Figs. 1 and 34).

CONCLUSION.

In reviewing the general features of the embryology of *Penilia* certain characteristics present themselves prominently throughout its development. The orientation of the egg is one of these.

An embryo always arises whose anterior end corresponds to the same end of the egg and whose long axis also agrees with that of the egg. Whether this is brought about by inherent differentiation of the egg protoplasm or whether by external influences is impossible of demonstration. The egg of *Penilia* divides transversely to the long axis of the egg into two cells, and judging from the position of these two cells, the descendants of the anterior one must have most to do with the formation of the anterior end of the embryo and the posterior one most to do with the formation of the posterior end of the embryo. The first two cells are certainly not right and left in that their descendants form those halves of the body of the adult, as Roux found for the frog's egg or Watake for cephalopod eggs, but rather as Wilson found for *Nereis*, where the first cleavage is also transverse to the future animal.

Grobben oriented the egg of *Moina* by means of the polar body which lies in the substance of the egg. This body marks the animal pole, and the cell containing it in the two-celled embryo by its development gives rise to the left side of the animal.

The segmentation of *Penilia* is total and remains so throughout, in marked contrast to most of the Crustacea. *Lucifer* and *Euphausia* are the known exceptions in the higher forms.

Much less yolk is present in the egg of *Penilia* than in most Crustacea even in nearly related forms, and the segmentation cavity never at any time possesses a yolk plug as is found in *Moina*.

One of the facts most frequently quoted from Grobben's article is the very early differentiation of one cell destined to give rise to the reproductive organs. Samassa also finds in *Moina* the same cell,

but he is unable to distinguish it from its fellows after it has subdivided into eight cells. He cannot trace it as the mother-cell of the genital organs, and from my work on *Penilia* and Lebedinsky's on *Daphnia* it is evident that Grobben's results are not confirmed.

Certain facts in the development of *Penilia* lead me to think that it is a highly specialized rather than a primitive cladoceran. The second maxillae appear as late and disappear much sooner than they do in *Moina*. The dorsal gland is weakly developed in comparison with other members of the group and lingeous a shorter time. The entoderm is nearly distinct as such from its origin and is never at any time intermingled with the mesoderm as it is in *Moina*. McMurrich thinks the origin of the entoderm and mesoderm together is the rule for the entire crustacean group. In the method of forming the eggs it resembles what is found in other Cladocera, since the egg is here apparently the survivor of four ovarian cells which unite to give rise to but one with little yolk. All of these facts indicate a specialized type.

Penilia also presents other characteristics considered primitive for the Cladocera. Claus finds six pairs of thoracic appendages present in the metanauplius hatched from the winter egg of *Leptodora hyalina*, which he thinks must be considered the original or primitive number for the Cladocera. As we have seen, the presence of six pairs of thoracic appendages is the chief distinguishing feature of *Penilia*. If Claus's view be the correct one, then *Penilia* must have branched off from the cladoceran stem quite early but yet late enough to have inherited the peculiar yet characteristic method of forming its eggs each from four equal ovarian cells.

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EXPLANATION OF PLATES.

ABBREVIATIONS USED.

<i>Ant.</i>	Anterior.
<i>Ant. 1.</i>	1st antenna.
<i>Ant. 2.</i>	2d antenna.
<i>B. C.</i>	Blood corpuscle.
<i>Bl.</i>	Blastopore.
<i>Br.</i>	Supra-esophageal ganglion.
<i>Br. Ch.</i>	Brood-chamber.
<i>C.</i>	Supra-esophageal commissure.
<i>Cer. Gl.</i>	Cervical gland.
<i>Ect.</i>	Ectoderm.
<i>End.</i>	Endopodite.
<i>Ent.</i>	Entoderm.
<i>Ey.</i>	Eye.
<i>Ex.</i>	Exopodite.
<i>G.</i>	Fold between the two rudiments of the nervous system.
<i>Ht.</i>	Heart.
<i>Int.</i>	Intestine.
<i>L.</i>	Upper lip.
<i>Ms.</i>	Mesoderm.
<i>Mx. 1.</i>	1st Maxilla.
<i>Mx. 2.</i>	2d Maxilla.
<i>Mx. r.</i>	Maxillary region.
<i>Post.</i>	Posterior.
<i>Sh.</i>	Shell.
<i>Sh. Gl.</i>	Shell-gland.
<i>Th. Seg.</i>	Thoracic segments.
<i>1, 2, 3, 4, 5, and 6.</i>	1st, 2d, 3d, 4th, 5th, and 6th thoracic segments.

PLATE 1.

- Fig. 1. Adult seen from the side; brood-chamber contains three young, the most anterior of which is rotated in the opposite direction from the one usually seen.
- Fig. 2. Adult seen from the dorsal side. The most anterior embryo on the left side has turned its dorsal side uppermost. The remainder have assumed the typical position.
- Fig. 3. Brood-chamber of adult containing eggs in the four-cell stage. Seen diagonally (dorso-laterally).
- Fig. 4. Brood-chamber of adult containing four eggs in the thirty-two cell stage. Seen from the dorsal surface.
- Fig. 5. Side view of a brood-chamber showing embryos with three thoracic segments. The most anterior embryo has its ventral surface turned inward and down.
- Fig. 6. Brood-chamber of an adult *Penilia* seen from the dorsal side. It contains four embryos in an advanced stage of development; all of which present their ventral surface to view.

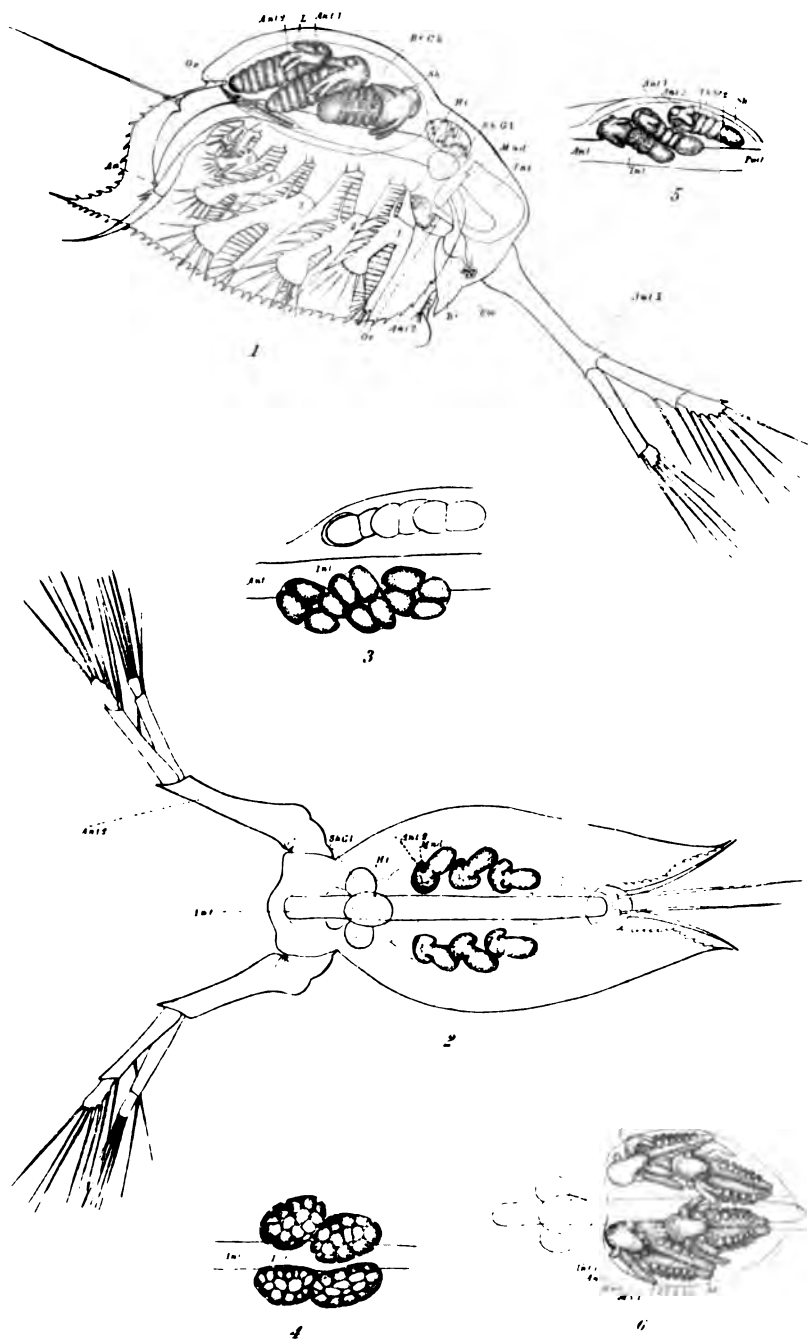


PLATE 2.

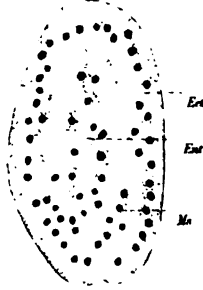
- Fig. 7. Two-cell stage of the segmenting egg.
- Fig. 8. Four-cell stage.
- Fig. 9. Eight-cell stage.
- Fig. 10. Sixteen-cell stage.
- Fig. 11. Thirty-two cell stage.
- Fig. 12. Sixty-four cell stage (section).
- Fig. 13. Section of egg having about one hundred and twenty-eight cells and showing the beginning of gastrulation.
- Fig. 14. A more advanced stage of the same process.
- Fig. 15. A still older stage showing the gastrula mouth at its greatest degree of development.
- Fig. 16. A section of a larva having all three germ layers differentiated.
- Fig. 17. A horizontal section of a larva which has the first rudiments of the two most anterior appendages.
- Fig. 18. Ventral view of an embryo whose outward form is beginning to change.
- Fig. 19. An older stage than the preceding seen from the ventral surface and showing the first traces of the first antennae.
- Fig. 20. An older stage seen from the ventral side and showing the broadening at the anterior end and elongation of the embryo.
- Fig. 21. An embryo seen from the ventral side showing the first and second antennae and rudiments of the mandibles.
- Fig. 22. An embryo with the first three pairs of appendages clearly defined and a maxillary region marked off seen from the ventral side.
- Fig. 23. A transverse section just behind the second antennae of a stage corresponding with Fig. 21.
- Fig. 24. A transverse section of the same embryo nearer the head.



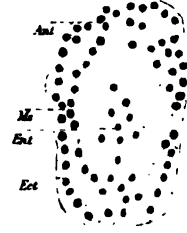
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8.



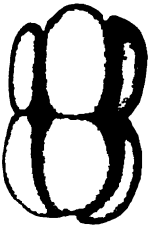
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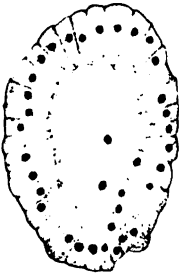
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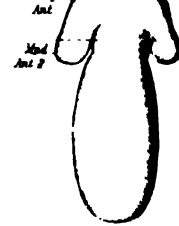
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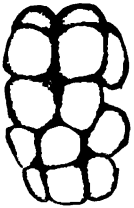
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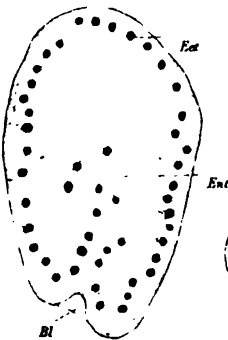
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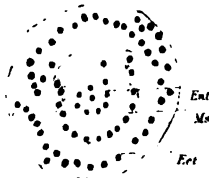
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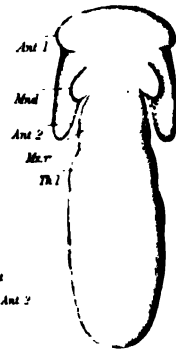
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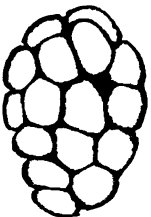
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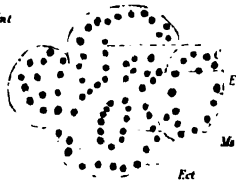
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22.



11.

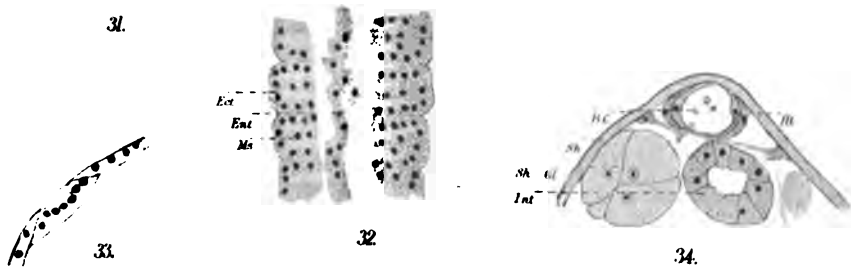
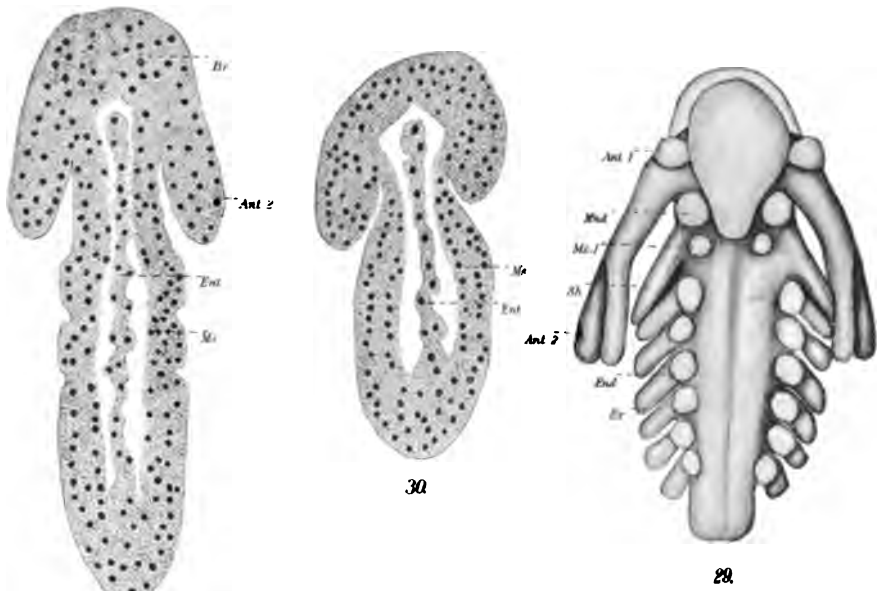
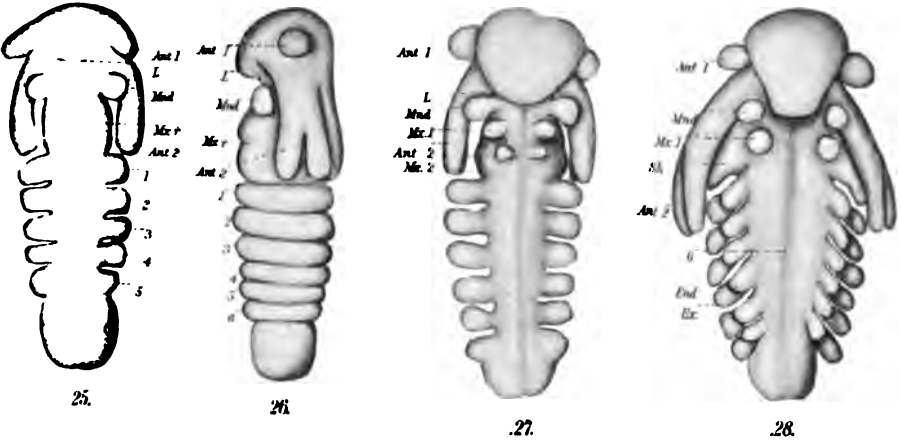


24.

W. H. SUDLER, DEL.

PLATE 3.

- Fig. 25. An embryo seen from the ventral side and which has five pairs of thoracic appendages in addition to those seen in Fig. 22.
- Fig. 26. A slightly older stage seen from the left side.
- Fig. 27. Ventral view of an embryo, at a stage when both the first and second maxillae are present.
- Fig. 28. Ventral view of an older larva. In this specimen the shell (Sh.) has assumed quite definite proportions.
- Fig. 29. An embryo that has assumed somewhat the size and relations of parts as seen in the adult, seen from the ventral side.
- Fig. 30. A horizontal section of an embryo at a stage a little older than represented by Fig. 21.
- Fig. 31. A horizontal section of an embryo somewhat younger than that seen in Fig. 25.
- Fig. 32. A horizontal section to show the arrangement of entoderm, mesoderm, and ectoderm of the thoracic region at a stage represented by Fig. 26.
- Fig. 33. A section through the anterior dorsal angle of an embryo showing the cervical gland at the stage of its maximum development.
- Fig. 34. A transverse section of an embryo at a stage corresponding to Fig. 28 to show the heart, intestine, and shell-glands.



No. 7. — *List of Marine Mollusca of Coldspring Harbor, Long Island, with descriptions of one new Genus and two new Species of Nudibranchs.*

By FRANCIS NOYES BALCH, CAMBRIDGE, MASS.

With one plate.

THE following list of Mollusca—representing eight weeks' work during August and September, 1898, and September, 1899, at the Biological laboratory of the Brooklyn institute of arts and sciences at Coldspring Harbor, Long Island, under the direction of Dr. C. B. Davenport—claims no especial extent, completeness, or novelty. It is put on record as a contribution toward more exact knowledge of local distribution and variation and because the nature of the locality gives it a certain interest. It represents a fairly distinct facies of molluscan life—the fauna of the oyster beds, broadly speaking. From this point of view its homogeneity and the absence of stragglers lend it value. Probably almost every species enumerated lives on the spot where found or in the immediate vicinity. This characteristic makes it a good sample of actual conditions of life in that interesting transition region where the “Virginian” and “Acadian” (or “Boreal”) faunas overlap. From this point of view it is, so far from being homogeneous, strikingly heterogeneous.

Coldspring Harbor (Davenport, '98) is an indentation some five miles long and one mile wide opening into Long Island Sound some forty miles east of New York. It is shoal (for the most part less than two fathoms), land-locked, tranquil, warm, muddy, and subject to a constant inflow of detritus and fresh-water from the high moraine hills surrounding it and abounding in streams. The shores are little varied. Commonly, a narrow strip of salt marsh leads to mud flats, to eel-grass beds, to oyster beds; or the steep “slides” of the carved moraine run down to a narrow beach of loose sand and stones thinly strewn with glacial boulders which shelves gently to the mud flats again. Genuine sand beaches are wanting, sandy bottom is rare, though sand often underlies the silt at the depth of a few feet. Rocky habitats other than the smooth and inhospitable boulders are few, though piles, sea walls, and old

hulks furnish some crevices and foothold for certain species. Gravel and stones cover small areas off the "points" where the glacial hills make out. The rest of the bottom is mud, thickly strewn with oyster, quahog, and "jingle" shells. The "Upper Harbor" — almost cut off by a sand-spit — in which the specific gravity of the water is at times lowered to 1.006, forms a mud bed, rank and black, covered with *Ulvae*, in which the brackish-water forms abound and the transition from marine to fresh-water and to land forms is almost imperceptible.

Professor Verrill ('73) has analyzed the fauna of the New England region according to environment, and gives a list of Mollusca characteristic of each station. Below is given his analysis (slightly rearranged) showing the per cent occurrence for each station at Coldspring Harbor of his characteristic forms for each station.

1. *Harbors, estuaries, ponds, or marshes.*—

- | | | |
|---|---|--------|
| a. Sandy shores and bottoms = 100% | } | = 89%. |
| b. Muddy shores and bottoms = 88% | | |
| c. Oyster beds in brackish water = 91% | | |
| d. Eel grass in brackish water = 80% | | |
| e. Submerged woodwork, etc.; brackish water = 87% | | |

2. *Bays and sounds.*—

- | | | | | |
|--------------------------------------|---|-----|---|--------|
| a. Rocky shores = 74% | } | 80% | } | = 74%. |
| b. Sandy shores = 93% | | | | |
| c. Muddy shores = 78% | | | | |
| d. Submerged woodwork, etc. = 74% | | | | |
| e. Rocky bottoms = 72% | } | 68% | | |
| f. Gravelly and shelly bottoms = 54% | | | | |
| g. Sandy bottoms = 76% | | | | |
| h. Muddy bottoms = 71% | | | | |

3. *Ocean shores and outer waters.*—

- | | | | | |
|------------------------------------|---|-----|---|--------|
| a. Rocky shores = 54% | } | 72% | } | = 59%. |
| b. Sandy shores = 90% | | | | |
| c. Rocky bottom = 55% | | | | |
| d. Sandy and gravelly bottom = 59% | } | 50% | | |
| e. Muddy bottom = 38% | | | | |

Examination shows that from the "Harbors, estuaries, ponds, and marshes" 89% are present at Coldspring Harbor, from the "Bays and sounds" 74%, and from the "Ocean shores and outer waters" only 59%. Again, from the shore and shoal-bottom

(3 fathoms?) stations 80% are present, while from the deeper waters we have only 59%. But a cross analysis according to other characters shows a very different result, for from all the muddy habitats we have 68%, from gravelly and shelly 68%, from woodwork and rocky 68%, while from sandy we have 89%. This last, however, should be thrown out entirely, since Professor Verrill gives very few species as characteristic of sandy shores and bottoms and those few are common forms of wide distribution, all occurring at Coldspring Harbor in mud.

The conclusion is that the molluscan fauna of Coldspring Harbor, in spite of the well-marked character of the place as "muddy," is determined, not at all by that character, but preponderatingly by the depth of water and by the factors included in the "enclosedness" of the place—that is, I suppose, by the temperature, the tranquility, the specific gravity, the per cent. of organic matter, etc. It looks as though the various species would manage somehow to be represented on almost any stretch of shore or bottom provided only the *water conditions* be right. This conclusion premises that shore and bottom were relatively equally explored, which was probably the fact. My conclusion is, of course, not inconsistent with Professor Verrill's analysis, as his groupings would still represent all they were intended to, viz., optima.

The Mollusca found were distributed, omitting doubtful occurrences or identifications as follows:—

<i>Cephalopoda</i> ,		Opisthobranchiata.	
Decapoda, 1.	1.	Tectibranchiata, 2.	} 9.
<i>Gasteropoda</i> ,		Ascoglossa, 1.	
Amphineura, 1.	1.	Nudibranchiata.	
Prosobranchiata.		Kladohepatica, 4.	
Docoglossa, 1. }		Holohepatica, 2.	
Ptenoglossa, 1. }		Pulmonata.	
Taenioglossa, 16. }	. 36.	Bassomatophora, 2.	2.
Gymnoglossa, 8. }		<i>Pelecypoda</i> ,	
Rachiglossa, 9. }		Protobranchiata, 3.	} 34.
Toxoglossa, 1. }		Filibranchiata, 6.	
		Pseudolamelli-	
		branchiata, 2.	
		Eulamellibranchi-	
		ata, 23.	
		Total, 63 genera, 83 species.	

Among these, apart from the nudibranchs, are no novelties or even great rarities, but the following are not in Professor Verrill's ('73) Report on the invertebrates of Vineyard Sound: *Littorina littorea*, *Assiminea modesta*, *Embletonia fuscata*, four species of Turbonilla, *Polycerella davenportii*, and *Corambella depressa*, while the range of *Astarte undata*, *Tergipes despectus*, *Hermæa cruciata*, and *Cratena gymnota* is extended west of the localities then known.

Sanderson Smith and Temple Prime ('70) published a report on the Mollusca of Long Island which represented eleven years' collecting and dredging and contained a great number of nominal species. It gave to the north side of Long Island inside of Montauk Point the equivalents of about 111 modern species, of which 71, or 64% are in my list which also contains 17 species not in Smith and Prime's list. The additions are *Littorina littorea*, *Alexia myosotis*, four species of Turbonilla, several nudibranchs, and *Mucoma sabulosa*, which last, however, is represented only by one worn valve whose occurrence may be accidental. The gaps in the list are perhaps more interesting than the occurrences. An eastern port where neither *Purpura lapillus* nor *Littorina irrorata* occurs is fairly well defined, geographically. Ten years ago it might have been possible to define the spot within 60 miles by saying it was a place where *P. lapillus* was not, and *L. littorea* was, found, but now the wave of the conquering European species has spread far down toward Virginia and at Coldspring the native competitor, *Nassa obsoleta*, begins to yield room. The Caecidae, *Bela*, *Lacuna*, *Skenea*, *Rissoa aculeus*, *Odostomia impressa* and *O. seminuda*, *Turbonilla interrupta* and *T. elegans*, the Elysiidae, *Corbula*, *Saxicava*, *Siliqua*, *Donax*, *Tellina tenella*, *Pholas*, all are conspicuous for absence and another summer might possibly account for some of them.

In the list of the Gasteropods as it stands 18 % are "northern" (i. e. forms characteristic of waters north of Cape Cod and usually not extending farther south than New Jersey unless in deep water), 41% are "southern" (i. e. forms extending south to Hatteras or Florida and found north of Cape Cod only in Massachusetts Bay or those scattered colonies of southern forms which still dot the coast up to Anticosti), while 42% are so general, so local, or so little known in distribution as to be unassignable to either category. Of the pelecypods 21% are "northern," 52% are "southern," and 27% are unassignable. Or, for the whole, 19+ % are "northern,"

45 + % are "southern," and 36 + % unassignable. I think the similarity of the figures in gasteropods and pelecypods considered separately shows that these percentages stand for a real fact of distribution. Two faunas overlap, the more southerly contributing rather more than twice as many species as the northerly.

The following species which do not occur at Coldspring Harbor (so far as known) are given by Perkins ('69) as occurring at New Haven on the opposite shore of Long Island Sound about forty miles to the eastward: *Amycla dissimilis* Stimps. (= *Astyris zonalis* Linsley), three specimens found among a lot of *A. zonata*; *Scalaria multistriata* Say (= *Scala m.* Say), very rare; *Odostomia dealbata* Stimps., very rare; *O. impressa* Stimps., not common; *O. seminuda* Gould (= *O. seminuda* C. B. Adams), very rare; *Pleurotoma brunnea* Perkins (= *Bela plicata* Adams), one specimen thrown up by the waves; *Simnia uniplicatula* Adams (= *S. uniplicata* Sowb.), one specimen probably brought up on southern oysters; *Rissoa aculeus* Stimps. (= *R. aculeus* Gould), common under stones and on algae near low water; *Rissoella? eburnea* Stimps. (= *Rissoa eburnea?* Stimps.) one beachworn specimen taken by Dr. Perkins which Verrill ('73, p. 655) remarks "may have been some other species. . . . I have seen no undoubted shells of this species south of Cape Cod"; *Skenea planorbis* F. & H. (= *S. planorbis* Fabr.), taken with *Alexia myosotis*, not common; *Lacuna vineta* Gould (= *L. vineta* Turton), not very common; *Littorina irrorata* DeKay (= *L. irrorata* Say), not at all common; *Tornatella puncto-striata* C. B. Adams (= *Actaeon p.* C. B. Adams), dead on the beach, not common; *Cylichna oryza* Stimps. (= *Cylichnella o.* Totten), dead on the beach, very rare; *Cyrtopleura truncata* Tryon (= *Pholas (Barnea) t.* Say), clay and peat at high water, not rare; *Martesia cuneiformis* Tryon (= *M. cuneiformis* Say), one specimen in a pile of beach shells; *Saxicava arctica* Linn., sand near low water, not common; *Corbula contracta* Say, sand at low water, not common; *Siliqua costata* Con. (= *S. costata* Say), very rare and small; *Angulus polita?* Tryon (= *Tellina p.* Say), a few specimens doubtfully so referred; *Kellia planulata* Stimps., in accumulations of small shells on shore, not common; *Brachydontes hamatus* Say (= *Mytilus h.* Say), abundant on southern oysters, doubtful if it is naturalized.

The following species occurring at Coldspring Harbor do not appear in Perkins's list: *Chuetopleura apiculata* Say, abundant;

Littorina littorea Linn., abundant; *Assiminea modesta* Lea, locally common; two species of *Turbonilla*, rare; *Hermæa cruciata* A. Ag., rare; *Cratena gymnota*? Couth., rare; *C. pilata* Gould, common; *Tergipes despectus* Johnst., rather rare; *Embletonia fuscata* Gould, rare; *Polycerella davenportii* nobis, locally not rare; *Corambella depressa* nobis, locally not uncommon; *Eriphyla lunulata* Con., rare; ?? *Lucina filosa* Stimps., a drift shell; *Macoma sabulosa* Spengler, a drift shell; *Gemma manhattensis* Prime, rather rare.

Doubtless a certain allowance must be made for doubtful identifications and not much importance can be attached to finds of one or two dead specimens on the beach, but it appears that there were resident at New Haven at least one *Astyris*, three *Odostomias*, one *Rissoa*, *Skenea*, *Lacuna*, *Littorina irrorata*, *Pholas*, *Saxicava*, *Corbula*, and *Siliqua*, which either do not live at Coldspring Harbor or are so excessively rare or so excessively local or capricious as to have escaped search. Any of them may yet be found there, however, and some, such as *Littorina irrorata*, probably will be. One very abundant *Chiton*, a highly local *Assiminea*, two species of *Turbonilla*, *Eriphyla*, and a southern variety of *Gemma* appear to be legitimate inhabitants of Coldspring Harbor, but not of New Haven. A comparison of the relative abundance of various species emphasizes the difference.

In Perkins's list, omitting the non-acclimatized forms imported on southern oysters (to which there is nothing corresponding at Coldspring Harbor), of the gasteropods 25—% are "northern," 48% are "southern," while 27+ % are unassignable. Rather curiously the pelecypods give the same figures so that the total is the same. In the Coldspring Harbor list, omitting the nudibranchs (which apparently were not collected by Dr. Perkins), of the gasteropods 14+ % are "northern," 49—% are "southern" while 36+ % are unassignable; of the pelecypods 23+ % are "northern," 52+ % are "southern," while 24+ % are unassignable; or for the total 18+ % are "northern" 50+ % are "southern" and 31+ % are unassignable. The omission of the nudibranchs emphasizes the southern aspect of the fauna on the face of the record, but there may well be doubt whether the attribution of many of the species to northern waters only is not a mere effect of our lack of knowledge of this group.

Doubtless figures like these give a false impression of accuracy, since opinion may differ as to whether to class a species as "south-

ern" or unassignable, but the striking correspondence between the figures for gasteropods and pelecypods and between the results for Coldspring and New Haven (results obtained at first by independent classings of the species which were only afterwards compared) shows, I repeat, that they represent real facts. The comparison between Coldspring and New Haven at least is just.

The upshot is, as before, that two pretty distinct faunas in this region overlap, the more southern one contributing a quota rather more than twice that of the more northern one; and further, the increase in the preponderance of southern forms can be detected in a range of forty miles.

In the list which follows the nomenclature adopted is that of Dall ('86, '89, '89) wherever possible, while in one instance I have followed Apgar ('91). The arrangement of the gasteropods is that of Fischer ('87), excepting the nudibranchs where I have followed Bergh ('92), and that of the pelecypods is that of Pelseneer ('94, '97). The only synonymy attempted in most cases is Verrill's names in his report ('73) and Smith and Prime's names in their report ('70), given for the sake of convenience in comparison.

I have adopted the scale of "very abundant" "abundant" "very common" "common" "tolerably common" "rather uncommon" "uncommon" "rare" and "very rare" as the best available way of describing the present condition of the molluscan population. Too vague to serve as an absolute measure it is yet to be hoped that it will prove accurate enough in relative terms to enable some future student to determine what changes in distribution and adjustment of equilibrium a given number of years may have made in the so-called "permanent residents" of a given locality. If it could be supplemented by a series of quantitative determinations of the actually prevailing "mode" in a series of the local forms it might prove a useful reference-point for future comparison.

A capital N or S following the synonymy will indicate that the corresponding species was counted as "Northern" or "Southern."

CEPHALOPODA.

LOLIGINIDAE.

Loligo pealii Les. Smith and Prime ('70), p. 405. Verrill ('73), p. 635. N.

One was taken in August, 1899, and specimens from the harbor

are preserved at the State fish commission, which has a station here. This species certainly occurs occasionally, if rarely.

GASTEROPODA.

AMPHINEURA.

POLYPLACOPHORA.

Chaetopleura apiculata (Say). Verrill ('73), p. 661. *Chiton* a. Smith and Prime ('70), p. 392. S.

Abundant and unusually large on, and especially in, old shells, etc., 1-3 fath.

PROSOBRANCHIATA.

DOCOGLOSSA.

Acmaea testudinalis (Müller). Verrill ('73), p. 661. *Tectura t.* Smith and Prime ('70), p. 392. N.

One shell, empty but fresh. Doubtless occurs very rarely on the more exposed points where beach boulders offer some poor foothold.

PTENOGLOSSA.

Scala lineata (Say). *Scalaria l.* Smith and Prime ('70), p. 394. Verrill ('73), p. 660. S.

One fine specimen, empty but fresh, buried in clean, sandy mud at low water.

TAENIOGLOSSA.

NATICIDAE.

Neverita duplicata (Say). Verrill ('73), p. 646. *Natica d.* Smith and Prime ('70), p. 396. S.

Common on the firmer bottoms at and below low water.

Lunatia heros (Say). Verrill ('73), p. 646. *Natica h.* Smith and Prime ('70), p. 395.

Common but less so than the preceding, with which it would seem to compete.

The var. *triseriata* (Say) Verrill ('73), p. 646. *Natica t.* Smith

and Prime ('70), p. 395, is abundant in deeper water where it out numbers either of the preceding.

CAPULIDAE.

Crepidula conveza Say. Smith and Prime ('70), p. 392. Verrill ('73), p. 650. S.

Common, but less so than the two succeeding species, and apparently seeks deeper water. Eggs still in the two-cell stage up to August 20.

Crepidula fornicata (Lam.). Smith and Prime ('70), p. 392. Verrill ('73), p. 649. S.

Abundant at and below low water on *Limulus*, *Fulgur*, etc. Eggs abundant in July and some still in 2-cell stage on August 23.

Crepidula plana Say. Verrill ('73), p. 650. *C. unguiformis* Lam. Smith and Prime ('70), p. 392. S.

Abundant on and in other shells, especially *Fulgur carica* and *F. canaliculata*.

LITTORINIDAE.

Littorina littorea (Linné). N.

Still a recent arrival (having reached New Haven only in 1880), and does not appear as yet seriously to threaten *Nassa obsoleta*, the native competitor for the mud flats. Far less abundant than *L. palliata* or *L. rudis*, from which it differs considerably in station, it is yet common on the edges of marsh and mud flat, and everywhere scattered sparsely among the *N. obsoleta*. It is not the clean dark shell of Massachusetts Bay, but dingy gray and green with vegetable growths like *N. obsoleta*, and appears to average larger than north of Cape Cod; the body-whorl seems more inflated, the suture less well marked. Bumpus's ('98) studies on the ventricosity of this species seem to confirm such a tendency in southern localities.

Littorina palliata (Say). Verrill ('73), p. 652. *L. littoralis* var. *peconica* Smith. Smith and Prime ('70), p. 393. N.

Abundant on sea walls, piles, and wherever *Fucus* will grow. As variable here as elsewhere.

Littorina rudis (Maton). Smith and Prime ('70), p. 392. Verrill ('73), p. 651. N.

Abundant with the preceding. Relatively more abundant in less brackish water. Extremely variable here as elsewhere.

RISSOIDAE.

Rissoa minuta (Totten). Smith and Prime ('70), p. 393. *Littorinella m.* Verrill ('73), p. 653. N.

Very common on *Ulva* and in black mud, upper harbor, in water almost fresh.

Rissoa laevis (DeKay). Smith and Prime ('70), p. 393. *Littorinella l.* Verrill ('73), p. 653. *Hydrobia?* *l.* Verrill ('82), p. 523. ? *Rissoa stimpsoni* Smith. Smith and Prime ('70), p. 393.

This and the preceding and two succeeding species are in such confusion as scarcely to repay any attempt to straighten out the nomenclature without further knowledge. Stimpson ('65) on the strength of the dentition and anatomy of *R. minuta* retained the genus *Littorinella* in his subfamily *Hydrobiinae* (= *Amnicolinae* of Gill) distinguished from *Rissoinae* on dentition alone, but suggested a new genus — *Ecrobia* — which Fischer ('87) adopts. The shell has also been referred to *Paludinella*, *Cingula*, and *Hydrobia*. As to *R. laevis* the case is much worse, for not only does it share the above changes but sometimes one appears in one genus or family and the other in another, while in truth the specific difference of the two is at least doubtful. As the dentition and anatomy of *R. laevis* have never been examined (so far as I know), any attempt to deal with the matter must be a guess. All that is said here applies to the two succeeding species. Dall recognizes only *minuta*, which he assigns to *Rissoa*, section *Cingula*. Whatever may be thought of the generic classification, the ignoring of the specific complications seems justified. Out of the hundred or so specimens examined from Coldspring Harbor two answered to the description of *R. laevis*; a few answered to the description of *R. stimpsoni* better than to that of *R. minuta*, while many answered equally to either; one answered better to the description of *R. latior* than to either of the others. It seems to be true that these variations (?) are local and that connecting series are not very complete.

? *Rissoa stimpsoni* Smith. Smith and Prime ('70), p. 393. Verrill ('82), p. 523. ? *Littorinella laevis* Verrill ('73), p. 653.

Cf. supra.

? ? *Rissoa latior* Stimps. Verrill ('73), p. 655.

Cf. supra.

ASSIMINEIDAE.

Assiminea modesta (Lea). Verrill ('84), p. 253. *Assiminea* ? Smith and Prime ('70), p. 393. *A. grayana* Leach. Verrill ('82), p. 525.

This shell, rediscovered by Verrill at Newport in 1880 and identified at the time as the English species *A. grayana* but afterward separated, apparently with some misgiving, and identified with Lea's *A. modesta* (Lea, '45), is one of the interesting occurrences. It was found in fair numbers on four particular stones in a sea wall and, in spite of careful search, nowhere else. These stones were covered by brackish water only for a few minutes at high tide but were always damp, being in the shadow of the gang plank to the Laboratory float-stage. Here the animals with their strangely aberrant fused eye-stalks and tentacles (?), their bright red buccal mass showing plainly through the pale flesh, and the translucent but solid chestnut shells with their apparent double suture and the sigmoid line of the intestine showing conspicuously on the body-whorl, might be found at any time to the number of three or four. After collecting all that could be found at one time, on the next day about the same number would appear on the same space of five feet by three, and nowhere else. Placed in salt water in the Laboratory, they crept out with all speed, and if at once put back three or four times they appeared eventually to become benumbed. There can be no doubt that the species is well separated from *A. grayana*, as the teeth (Pl. 1, fig. 11) show well-marked difference, but the identification with Lea's shell seems doubtful. Neither his figure nor his description agrees very well with my specimens, nor does Verrill's figure perfectly represent them, though his description of the shell does so. He has not described the animal, which has the foot broadly rounded in front, obtusely pointed behind, translucent yellowish white, bearing the operculum on the right side; the muzzle bilobed, slightly wrinkled, rather darker than foot, the red buccal mass plainly visible; tentacles and eye-stalks fused, forming thick, blunt, contractile peduncles, each bearing two conspicuous large black eye-spots, one anterior superior median, the other lateral anterior, the latter being the larger

by one third. The other American representatives of the genus, *A. auberiana* d'Orb. and *A. concinna* C. B. Adams, do not extend north of Tampa, Fla. It certainly is not common and appears to be very highly local, which would explain why a shell so conspicuous for everything but size has been so overlooked. If, as has been suggested (Cooke, '95), the presence of haemoglobin in the buccal mass is correlated with special muscular activity in those parts, this Assiminea should prove a real glutton. The animal proves itself very active on occasion.

TRIFORIDAE.

Triforis perversa (Linné) var. *nigrocincta* (Adams). Verrill ('73), p. 648. *Cerithium n.* Smith and Prime ('70), p. 394. S.

Uncommon. Under stones between tides. Locally on oyster beds. Dall makes it a variety of the European species. The protoconch of four whorls covered with a delicate yellowish red epidermis is unusually regular and no reminiscences of a dexter habit were detected.

CERITHIOPSIDAE.

Cerithiopsis greenii (C. B. Adams). Verrill ('73), p. 647. *Cerithium g.* Smith and Prime ('70), p. 394. S.

In September of 1899 one cast of the dredge on oyster beds brought up this species alive to the number of ten, the only occasion on which it occurred. With it were the young of *Seila terebralis* and adult specimens of *Triforis* in considerable numbers. This brilliantly colored little shell is a beautiful microscopic object. The three smooth, swollen, and irregular whorls of the protoconch, which are set over out of the axis of the shell, are succeeded by two whorls in which the adult beaded sculpture is gradually established, first appearing not as connected beads but as disconnected rings.

Seila terebralis (C. B. Adams). *Cerithiopsis t.* Verrill ('73), p. 648. *U. terebellum* Stimps. Smith and Prime ('70), p. 397. S.

Common alive on piles and *Ulva*, and (mostly dead) on shelly bottom. Young of 2.2 mm. taken in the middle of September show a protoconch of three swollen yellowish white whorls succeeded by a whorl showing distinct reminiscences of a beaded sculpture, after which the regular corkscrew pattern comes in.

Eumeta subulata Montagu. *Cerithiopsis emersonii* (C. B. Adams). Smith and Prime ('70), p. 397. Verrill ('73), p. 648. S. With the preceding but uncommon.

CERITHIIDAE.

Bittium alternatum (Say). *B. nigrum* (Totten). Verrill ('73), p. 648. *Cerithium sayi* Menke. Smith and Prime ('70), p. 394. S.

Abundant on the mud flats, on Ulva, etc. August 23d, young of 2-3 mm. and about 6 whorls were extremely abundant on black mud and sand in a few inches of water, almost covering the surface for some acres. 100 were easily picked from a square foot or two. The young at this stage and until they have attained a length of some 5 or 6 mm. show characters very different from the adult in color (which is darker), the sculpture, and the aperture, which is markedly different from,—and even less typically cerithioid than,—that of the adult. This young stage, presumably the first year's growth, is often discernible in the color and sculpture of the spire-whorls of the adult as Gould ('70) also has observed. A parallel stage in apertures appears in some West Indian species of *Cerithium*. No protoconch was observed.

GYMNOGLOSSA.

PYRAMIDELLIDAE.

Turbonilla sp.?

One specimen. Kindly identified for me by Miss Katherine J. Bush as species designated as f' in MS. of Bush and Verrill which it is to be hoped may be published soon.

Turbonilla sp.?

Common. Kindly identified by Miss Bush as species G."; cf. *supra*.

Turbonilla sp.?

Two specimens. Kindly identified by Miss Bush as species E."; cf. *supra*.

Turbonilla sp.?

Two specimens. Kindly identified by Miss Bush as species V; cf. *supra*.

ITALIAN HISTORY

1. 1848-1849

1848

1849

1848-1849

1848-1849

1848-1849

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1848-1849

1848-1849

1848-1849

cussion, the form called by Verrill *A. similis* is common at Cold-spring Harbor on shelly bottoms below tide marks. Among them occur a few specimens not connecting well with the common form and answering to Verrill's interpretation of *A. avara*. Judging from the general character of the fauna, it might be permissible to predict that the commoner form is the more southerly.

Astyris lunata (Say). Verrill ('73), p. 645. *Columbella l.* Smith and Prime ('70), p. 398. S.

Common everywhere below tides. Also on *Ulva*, etc. Very conspicuous for its extreme variability of color-pattern and its activity.

var. *gouldiana* Ag. MS. (Stimps.), = *Buccinum wheatleyi* DeKay, is tolerably common.

NASSIDAE.

Nassa obsoleta (Say). Smith and Prime ('70), p. 397. *Ilyanassa o.* Verrill ('73), p. 641.

Abundant everywhere, especially on mud flats where it is dominant.

Nassa vibex Say. Smith and Prime ('70), p. 397. Verrill ('73), p. 640. S.

Uncommon. Capriciously distributed among *N. obsoleta*, from which it is not always readily distinguishable. A fairly well-marked variety, perhaps = *N. fretensis* Perkins ('69), occurs, occasionally in some numbers, on eel-grass.

Nassa trivittata Say. Smith and Prime ('70), p. 397. *Tritia t.* Verrill ('73), p. 641.

Abundant in proportion as the situation becomes too exposed for *N. obsoleta*, and in deeper water.

TURBINELLIDAE.

Fulgur carica (Linné). Verrill ('73), p. 640. *Pyrula c.* Smith and Prime ('70), p. 398. S.

Common below tides, but less common than the following.

Fulgur canaliculata (Linné). *Pyrula c.* Smith and Prime ('70), p. 398. *Sycotypus c.* Verrill ('73), p. 640. S.

Very common, but not perhaps abundant, from 2 fathoms out.

TOXOGLOSSA.

CONIDAE.

- Mangilia cerina* (Kurtz and Stimps.). Verrill ('73), p. 637.
Pleurotema c. Smith and Prime ('70), p. 398. S.
One specimen from sandy mud in 7 fathoms.

OPISTHOBRANCHIATA.

TECTIBRANCHIATA.

TORNATINIDAE.

- Tornatina canaliculata* (Say). *Bulla c.* Smith and Prime ('70), p. 399. *Utriculus c.* Verrill ('73), p. 663. S.

Not uncommon below tide marks, but usually dead. The specimens fall into two well-separated groups, the first consisting of larger shells with yellow epidermis and tapered spire, the second of much smaller shells usually greatly eroded, the remains of the spire much thicker and flatter, the columella tooth less conspicuous. Some of the latter answer better to descriptions of *Retusa pertenuis* Mighels than they do to those of *T. canaliculata*. Why the old shells should have the epidermis usually intact while the young shells usually lack it, is a puzzle. The same thing is noticeable in *Cylichna alba* Brown, from more northern waters.

BULLIDAE.

- Haminea solitaria* (Say). *Bulla s.* Smith and Prime ('70), p. 399. Verrill ('73), p. 662. S.

Dead shells common in dredging. Rather uncommon alive. Occurs on marsh grass, top of sea wall, etc.

ASCOGLOSSA.

HERMAEIDAE.

- Hermaea cruciata* A. Agassiz MSS. Gould ('70), p. 253. Verrill ('73), p. 667.

Two specimens from *Ceramium* and other red sea-weeds on stony bottom off Lloyd's neck. Only once before reported, so far as I know, viz., by Agassiz at Naushon in 1863; but Professor Verrill informs me that he has taken it several times. Probably it is not so much rare as capricious in occurrence, like so many nudibranchs.

NUDIBRANCHIATA.

KLADOHEPATICA.

CRATENIDAE.

? *Cratena gymnota* (Couth.). Bergh ('92), p. 31. *Coryphella g.* Verrill ('73), p. 667.

These specimens, found depositing eggs on eel-grass, Aug. 26, were unfortunately not preserved for complete identification. They differed markedly from var. *gouldii* Verrill (Bergh ('92), p. 31, = *Montagua g.* Verrill ('73), p. 667), of which one specimen was taken from compound tunicates. On the authority of Professor Verrill this is made a variety of *C. gymnota*.

Cratena pilata (Gould). Bergh ('92), p. 31. *Montagua p.* Verrill ('73), p. 666. *M. vermifera* Verrill ('73), p. 666. *Aeolis vermiferus* Smith. Smith and Prime ('70), p. 391.

Common but of small size on hydroids from lobster-pot lines a fathom or two below the surface. Also in dredgings of eel-grass. On the authority of Professor Verrill *Aeolis vermiferus* Smith is reduced to synonymy. Specimens answering both descriptions were taken.

TERGIPEDIDAE.

Tergipes despectus (Johnst.). Verrill ('73), p. 667. Bergh ('92), p. 31. N.

Rather uncommon on hydroids from lobster-pot lines.

Embletonia fuscata Gould ('70), p. 251. Bergh ('92), p. 34. N.

Rather uncommon on hydroids from lobster-pot lines. This is the first reported occurrence south of Cape Cod so far as I know.

HOLOHEPATICA.

PHANEROBRANCHIATA.

POLY CERIDAE.

Polycerella davenportii sp. nov. Pl. 1, figs. 2-7.

Body limaciform, slightly constricted behind the rhinophores. Length 2-4 mm. Breadth (when creeping) about $\frac{1}{4}$ of length. Color dirty green, speckled with black and splashed with sulphur-yellow around and on rhinophores. Mantle distinct, without marginal flap, not covering the foot which is pale yellowish and long in extension posteriorly where it tapers evenly to a notched point. Anterior angles of foot moderately prolonged as oral palps, anterior margin usually salient. Rhinophores long (in extension $\frac{1}{4}$ length of body), heavy, clavate, simple, contractile, not foliate, laminate, or retractile, without sheaths. Gills three, small, rudimentary in appearance, dorsal, median, each consisting of a recurved stem bearing three posteriorly directed branches between which is stretched, in perfect specimens, a delicate web. The middle gill is set on the very conspicuous pulsating cardiac prominence and shows scarcely any branching, the web being thicker than in the lateral members. Occasionally a single rudimentary fourth branch anteriorly directed appears. Dorsal papillae not on edge of mantle, usually one pair in front of, one at level of, and one behind the gills. Two smaller pairs form a posterior rosette. Papillae small ($\frac{1}{4}$ length of contracted rhinophores), inconspicuous. Mouth anterior, funnel-shaped, dorsally exposed in extension, armed with thin mandibular lamellae. Anus, a transverse slit, median, dorsal, just behind and under gills. Radula almost as in *P. emertonii* Verrill ('80-81, p. 387; '82, p. 548), rhachidian tooth wanting; pleurae strongly hooked with accessory points, large; uncini two, sickle-shaped. Formula 2-1-0-1-2.

This odd little sea-slug is most nearly related to *P. emertonii* Verrill ('80-'81, p. 387; Bergh, '83, pl. 9, figs. 1-6 and pl. 8, figs. 9-19), which it resembles in general organization, color, size, and dentition and from which it differs in dentition (slightly), in the fewness and smallness of the papillae and the relatively much larger rhinophores, in the fact that the webbed gills are simply and singly pinnate instead of simply but doubly (alternately) pinnate, in the shape of the gills and number of their branches (which is much greater in *P. emertonii*), and finally in the character of the foot which in *P. emertonii* is covered by the mantle. Professor Verrill's great

kindness in showing me his unpublished sketches of *P. emertonii* has allowed me to satisfy myself of the very different appearance of the two. Were it not for the great similarity of the dentition *P. davenportii* would seem entitled to generic distinction on the ground of the very different gills and the uncovered foot. No armature of the penis could be made out in sections, but this was perhaps owing to poor preservation.

Specimens of *P. davenportii* were first taken on August 16 from hydroids on lobster-pot lines, and again about two weeks later appeared in jars of stones, weeds, hydroids, etc., which had been dredged in about 3 fath.

CORAMBIDÆ.

Corambella gen. nov. Pl. 1, figs. 12-15.

Form Corambe-like (cf. Bergh, '71 and '92, and H. Fischer, '91), but more convex and proportionately longer. Notaeum as in Corambe, but without the anal notch. Rhinophores not foliate laminate or branched; tapered, retractile, with sheaths. Anus and gills as in Corambe, viz.: anus median, posterior, between the foot and the gill plates, which lie posteriorly on either side between foot and notaeum, completely hidden by foot in life. Genital papilla anterior, left side, hidden in life. Jaws and pharyngeal bulb without plates or other armature. Radula large, no rhachidian tooth; pleurae large, twisted, the median ends bent up and back in a heavy hook; uncini five, stout, claw-shaped. Formula 5-1-0-1-5.

This genus is erected to contain a form closely allied to *Corambe sargassicola* Bergh and *C. testudinaria* H. Fischer, but not to be included within that genus because of the lack of the anal notch and the different dentition. The anal notch is by Bergh made a family character, yet no doubt the present form must fall within his Corambidae.

Corambella depressa sp. nov.

Form Doris-like, much flattened in life, broadly rounded in front and bluntly tapering posteriorly. Length 5 mm., breadth 3 mm. Color sometimes dull brown with gray irregular reticulation, but occasionally rather bright and conspicuous, when a translucent dull blue ground-color is indistinctly, coarsely, and irregularly blotched with dirty green or greenish brown and irregularly scattered with small black spots, the pattern darker and closer toward the center, producing a radial effect. Between the blotches in every direction run very conspicuous opaque yellowish white lines like the borings of larvae under

bark, becoming coarser toward the margin and heightening the radial effect of the whole. These lines serve to pick out smartly the rhinophore openings. In formol specimens the color becomes black, and in specimens cleared and viewed by transmitted light a coarse reticulation around the edge of the notaeum becomes very conspicuous especially posteriorly. Notaeum loose and amply covering all parts, often up-turned at the margin in life; dorsal aspect, which in life is smooth, has a shagreen-like surface in preserved specimens from the calcareous particles of the integument. Foot rather long, bluntly tapered, anteriorly strongly cordate, posteriorly roundly pointed in life (in preserved material usually emarginate). Oral disc only as broad as foot, strongly convex anteriorly; oral palps very thick and short. Rhinophores long ($\frac{1}{4}$ maximum breadth of specimen), evenly tapered, covered for about half the length by a delicate white sheath. Entirely retractile together with sheath. Gills, which are most of the time hidden in living animals, lie posteriorly in the space between foot and notaeum, and consist of a set of simple overlapping plates on each side of the cardiac vessel which unites them. These, together with the anal papilla which lies ventral and anterior to the heart in the median line, are only exposed in a few even of the preserved specimens. On the left side, just behind the neck, lies the genital opening from which the genitalia are usually everted in preserved material even when the animals were first stupetized with magnesium sulphate. In some sections through this sexual extrovert there appeared strongly-staining plumose structures at first suggesting gills and possibly representing a complicated armature of the penis but not positively identified by me. No signs of mandibular lamellae, or of the horny "Balken" described from the mouth cavity of *Corambe*, appear. The radula is described *supra*.

Unfortunately this inconspicuous little nudibranch, which occurred during August in fair numbers under stones on which *Fucus* was growing on the edge of swift water, and in dredgings of stones and weed from 2 fathoms, was at first taken for *Doridella obscura* Ver-rill ('73, pp. 400 and 664) and ('81-'82 p. 547) and therefore only casually studied and sketched in life. Consequently I am uncertain what is the exact structure of the rhinophore and sheath, but probably, as in *Corambe*, the sheath is longitudinally slit on its posterior (superior) face and the rhinophore itself is, for the projecting portion, a sheet with the edges rolled inward posteriorly, as the comparison of my sections with Fischer's ('91) very complete account of the anatomy of *Corambe testudinaria* makes it clear that almost all the structures bear some general resemblance to that species. As the animal, in which periods of considerable activity appear to alternate with periods of obstinate passivity, creeps on the under surface of the water the rhinophores are commonly turned back in a graceful curve on each side. The gills are

usually hidden, but rarely the progress of the animal is stopped, the foot, which before extended beyond the mantle border, retracted, and the extremely delicate and glassy gill-plates rapidly thrust in and out first on one side then on the other, at such times closely resembling the tips of some small beetles' wings thrust from under the elytra. The form of the notaeum varies constantly in life, often appearing broadest posteriorly and sometimes slightly emarginate there but never so broad as long.

The relation of this form to Verrill's *Doridella obscura*, which it somewhat resembles superficially, is interesting but rather uncertain. Both Fischer and Bergh placed *Doridella* in the genus *Corambe* on the supposition that the anal notch had been overlooked and on the strength of the general likeness. But Verrill's further description of the rhinophores as simple and without sheaths and of the gills as "tufted" and situated on the right (left?) side *near* the end would remove it not only from the genus *Corambe* but from the family of *Corambidae*. As the structure of *Doridella* is entirely unknown, placing it is only guess-work, but if it proves to be a corambid form, as seems likely, the distribution of this family of six species will be curious, viz.: one species in the Sargasso Sea (Bergh, '71), one in the Zuyder Zee (H. Fischer, '91), one in the China Sea (Adams, '58), one in the North Sea (Herbert, '86), all these of one genus, and two in Long Island Sound occupying the same station and belonging to different genera.

PULMONATA.

BASSOMATOPHORA.

AURICULIDAE.

Alexis myosotis (Drap.). Verrill ('73), p. 662. N.

On stones at and above high-water mark. Usually near brackish water. Sometimes associated with *Assimineia modesta*. Uncommon.

Melampus lineatus Say. *M. bidentatus* Verrill ('73), p. 662. *M. corneus* Smith and Prime ('70), p. 399. S.

Common on edges of salt marsh, on grass stems, etc. The banded variety occurs sparingly.

PELECYPODA.

PROTOBRANCHIATA.

NUCULIDAE.

Nucula proxima Say. Smith and Prime ('70), p. 385. Verrill ('73), p. 691.

Abundant everywhere on muddy or shelly bottoms below 1 fath.

LEDIDAE.

Yoldia limatula (Say). Verrill ('73), p. 689. *Leda limatula* Smith and Prime ('70), p. 385.

Locally common in black mud, 3-6 fath., and attaining a length of $1\frac{1}{4}$ inches. The number of teeth is variable, ranging from 16 anterior and 13 posterior to 26 anterior and 24 posterior, so that the numbers usually given on the authority of Gould (22-18) are misleading. Probably, as Professor Verrill believes, they increase with age, but it is easy to find small specimens with many and large specimens with few teeth. In shape the specimens are all nearly typical *limatulas*, the form separated as *Y. sapotilla* not occurring.

SOLENOMYIDAE.

Solenomya velum Say. Smith and Prime ('70), p. 389. Verrill ('73), p. 688.

Locally not uncommon at and below low water; occurs a foot or so below the surface of the fine clean sand and mud in which it lives.

FILIBRANCHIATA.

ANOMIIDAE.

Anomia simplex d'Orbigny. *A. ephippium* Smith and Prime ('70), p. 384. *A. glabra* Verrill ('73), p. 696. S.

Extremely abundant everywhere. In many places the dredge comes up filled with the dead shells to the exclusion of almost everything else.

ARCIDAE.

Arca transversa Say. Smith and Prime ('70), p. 384. *Scapharca t.* Verrill ('73), p. 691. S.

Common on shelly bottom, 2 fath. and below.

Arca pezata Say. Smith and Prime ('70), p. 385. *Argina p.* Verrill ('73), p. 692. S.

Occurs with the last species but not one fifth as common. Perkins ('69) notes the opposite condition at New Haven. Neither of these "bloody-clams" appears to have the deep-burrowing habit which Lankester's explanation ('73) of the presence of haemoglobin in the blood calls for.

MYTILIDAE.

Mytilus edulis Linné. Smith and Prime ('70), p. 386. Verrill ('73), p. 692. N.

Abundant everywhere, but the great "mussel-ridges" so characteristic of some waters do not occur; Gould's var. *pellucidus* is not uncommon.

Modiola modiolus (Linné). Verrill ('73), p. 693. *Mytilus m.* Smith and Prime ('70), p. 386. N.

No live specimens were taken, but doubtless the species occurs in the harbor as very fresh valves were tolerably common in the dredge at certain spots.

Modiola plicatula Lam. Verrill ('73), p. 693. *Mytilus p.* Smith and Prime ('70), p. 386. S.

Abundant everywhere, especially about salt marshes.

Specimens from a certain marsh near Lloyd's Harbor show curious distortion and erosion effects so constant as to resemble a real variety; but doubtless the erosion, which is sharply confined to the beaks which are buried in the soil, is due to the presence of humous or other acids and probably the distortion is due to the same cause. In the same marsh the clam shells were very curiously distorted; *cf. infra.*

PSEUDOLAMELLIBRANCHIATA.

OSTREIDAE.

Ostrea virginica Gmelin. *O. virginiana* Smith and Prime ('70), p. 384. Verrill ('73), p. 697. *O. borealis* Smith and Prime ('70), p. 384. *O. costata* Smith and Prime ('70), p. 384. S.

Abundant, but largely artificially planted. Owing to the low specific gravity of the water and the abundant food this is a famous fattening ground and the industry is the principal one of the place. In 1898 the natural "set" was very small (as it had been for several years), owing, as the fishermen believed, to severe thunderstorms during the period when the "fry" were "swimming" which they variously estimate at from July 25 to August 7. In 1899 the "set" was heavy. The method of cultivation here is simply to clear the ground of "wrack" and "sludge" and plant "native" oysters (mostly from Bridgeport, Conn., which has oysters in abundance but no such fattening-ground as this) on grounds in the outer waters specially prepared by "cleaning up" and then spreading gravel of such a size that each oyster may attach itself to a separate base instead of growing in bunches. As the young approach marketable size they are moved farther up the harbor to fatten.

PECTINIDAE.

Pecten irradians Lam. Smith and Prime ('70), p. 384. Verrill ('73), p. 695. S.

Abundant on eel-grass beds in outer harbor. The spat covered the eel-grass on Aug. 4th. Scallops are to some extent cultivated like oysters here, but the industry does not attain to the importance it does in Buzzard's Bay and on some parts of Cape Cod.

EULAMELLIBRANCHIATA.

ASTARTIDAE.

Astarte undata Gould. Verrill ('73), p. 684. *A. sulcata* Flem. Smith and Prime ('70), p. 387. N.

One live specimen from gravel and shelly bottom in 4 fath. This was one of the surprises of dredging, as the species is here at

its extreme southern limit, I believe, as a shoal-water form, and 4 fath. would be above its usual habitat even in much more northern waters. But the animal was alive and admitted of no doubt in identification. Smith and Prime admit the species only doubtfully on the authority of De Kay as "rare" and assign it a range from Stonington north, so this is really an addition to their list. Verrill mentions no locality west of New Haven, where Dr. Perkins found *var. lutea* (= *Astarte lutea* Perkins).

Astarte castanea (Say). Smith and Prime ('70), p. 387. Verrill ('73), p. 685. N.

A few live specimens in black mud, 3-4 fath., and a few old valves. Rare.

?? *Astarte quadrans* Gould. Verrill ('73), p. 685.

It is doubtful whether the shell so identified was correctly placed, even supposing this to be a good species. It is at all events a marked variant from the preceding.

CRASSATELLIDAE.

Eriphyla lunulata (Conrad). *Astarte l.* Smith and Prime ('70), p. 387. *Gouldia mactracea* Gould. Verrill ('73), p. 685. S.

One dead specimen, fairly fresh, and several much worn valves from hard bottom in 4 fath.

LUCINIDAE.

?? *Lucina filosa* Stimps. Verrill ('73), p. 686.

A very small shell, about 5 mm. high, extremely compressed and with very conspicuous concentric lamellae, is assigned to this species with the greatest uncertainty. It was at first taken for the young of *Venus mercenaria*, which it much resembles, but there is no pallial sinus, and the teeth, though so undeveloped as to be equivocal, point to the Lucinidae. Being eroded and immature, it is beyond positive identification and may have come from a distance, very possibly carried by some fish.

TELLINIDAE.

Tellina tenera Say. Smith and Prime ('70), p. 389. *Angulus tener* Verrill ('73), p. 677. S.

Tolerably common in black mud, 3-4 fath.

Mucoma tenta (Say). Smith and Prime ('70), p. 389. Verrill ('73), p. 678. S.

Locally abundant in black mud below tide marks.

Macoma balthica (Linné). *M. fragilis* Adams. Verrill ('73), p. 676. *Tellina fusca* Philippi. Smith and Prime ('70), p. 389.

Dead but perfectly fresh and unusually large specimens locally common 1-3 feet deep in black mud at low-water mark in Upper Harbor. The animals doubtless live in numbers close by, probably deeper in the soft mud, although in more northern waters and on harder ground it may be found alive free upon the surface. The rather surprising combination of the heavy shell and epidermis characteristic of muddy localities with the brilliant rose color usually seen only in small shells from clean sand occurs.

Mucoma sabulosa (Spengler). Verrill ('73), p. 677. N.

One valve found by Dr. J. I. Hamaker was so identified by him.

SEMELIDAE.

Cumingia tellinoides (Conrad.). Smith and Prime ('70), p. 388. Verrill ('73), p. 679. S.

A few valves on hard bottoms in 4 fath. Rare.

MACTRIDAE.

Macatra solidissima Dillwyn. Smith and Prime ('70), p. 388. Verrill ('73), p. 680.

Relatively not very common or very large. Lives in mud and sand in more exposed situations.

Macatra lateralis Say. Smith and Prime ('70), p. 388. Verrill ('73), p. 680. S.

Abundant in black mud below tide marks, slightly buried.

VENERIDAE.

Venus mercenaria Linné. Smith and Prime ('70), p. 388. Verrill ('73), p. 681. S.

Very abundant below tide marks. A considerable clam-fishery exists.

Cytherea convexa Say. Smith and Prime ('70), p. 388. *Calista c.* Verrill ('73), p. 681. N.

Rather uncommon on soft bottom, 3-4 fath.

Gemma purpurea H. C. Lea. *Venus gemma* Totten. Smith and Prime ('70), p. 388. *Tottenia gemma* Verrill ('73), p. 682.

Locally abundant, lying on the surface of black mud and fine gravel on the flats.

var. *manhattensis* Prime. *Venus m.* Smith and Prime ('70), p. 388. *Tottenia m.* Verrill ('73), p. 682. S.

A few specimens so identified occurred capriciously among the *G. purpurea*. Rare.

PETRICOLIDAE.

Petricola pholadiformis Lam. Smith and Prime ('70), p. 390. Verrill ('73), p. 680. S.

Common, boring in the salt marsh among roots of grass, etc., at top of beach.

CARDIIDAE.

Cardium pinnulatum Conrad. Smith and Prime ('70), p. 387. Verrill ('73), p. 683. N.

One live and several dead specimens on hard bottom in 6 fath. Rare.

Liocardium mortoni (Conrad). *Cardium m.* Smith and Prime ('70), p. 387. *Laevicardium m.* Verrill ('73), p. 683. S.

Abundant in soft mud at and below low water.

MYIDAE.

Mya arenaria Linné. Smith and Prime ('70), p. 390. Verrill ('73), p. 672.

Abundant but not large. In the marsh before mentioned (see under *Modiola plicatula*) occurred a distorted variety, heavy, truncated, and gaping, which resembled the circumpolar *Mya truncata* Linn. almost exactly, even to the tough and persistent epidermis. I think it would scarcely be distinguished from specimens of *M. truncata* lacking the epidermal tube. Perhaps adverse circumstances in both cases have produced parallel results. Doubtless the thick epidermis is a protection from the acids of the marsh.

SOLENIIDAE.

Ensis americana (Gould). *Ensatella a.* Verrill ('73), p. 674.
Solen ensis Linné. Smith and Prime ('70), p. 389.

Tolerably common in sand or clean mud at and below extreme low water.

PANDORIDAE.

Clidiophora gouldiana Dall. *C. trilineata* Verrill ('73), p. 673.
Pandora t. Smith and Prime ('70), p. 390.

Locally common in black mud, 3-6 fath., with *Yoldia limatula*.

LYONSIDAE.

Lyonsia hyalina (Conrad). Smith and Prime ('70), p. 390.
Verrill ('73), p. 672.

Rather uncommon. Locally on hard bottom in 3-6 fath.

TEREDIDAE.

Teredo navalis Linné. Verrill ('73), p. 669. S.

Not uncommon. The submerged timber is honey-combed by ship worms, but in only a few instances was the species determined. Of these all but one were of this species.

Xylotrya fimbriata Jeffreys. Verrill ('73), p. 670. S.

Found in an old hull.

Besides the above, fourteen species of land and fresh-water shells occurred in the immediate vicinity of the Laboratory; and some of them occasionally in company with *Alexia myosotis* and *Melampus lineatus* given above as marine.

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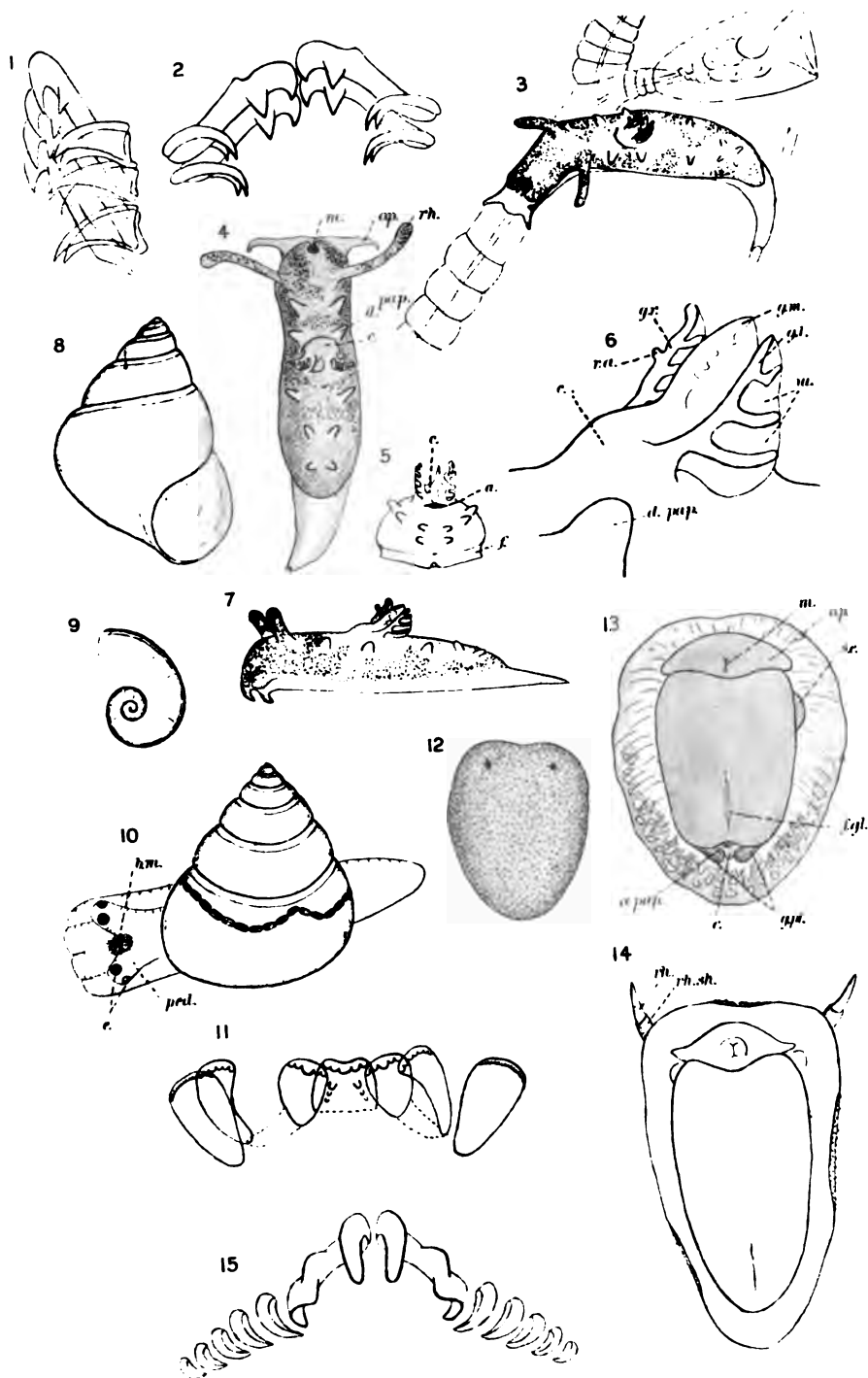
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- Fig. 1. A part of the radula of *Polycerella emertonii* Verrill (from Bergh '83).
- Fig. 2. Two rows of teeth from the radula of *Polycerella davenportii*. oc. 3. \times oil immersion $\frac{1}{2}$.
- Fig. 3. A small specimen of *Polycerella davenportii* creeping on a hydroid stem. The animal drawn from a specimen of $1\frac{1}{2}$ mm.
- Fig. 4. *Polycerella davenportii*, dorsal aspect. m. = mouth, o. p. = oral palps, rh. = rhinophore, d. pap. = dorsal pappilla, c = cardiac prominence. From a specimen of 3 mm.
- Fig. 5. *Polycerella davenportii*, posterior aspect. a. = arms, f. = foot.
- Fig. 6. *Polycerella davenportii*, enlarged outline of gills and cardiac prominence. g. m. = medial gill, g. r. = right gill, g. l. = left gill, w. = web, r. a. = rudimentary anterior branch.
- Fig. 7. *Polycerella davenportii*, side view. From a specimen of 4 mm.
- Fig. 8. Shell of *Assiminea modesta* Lea. After camera sketch. $\times 35$.
- Fig. 9. Operculum of *Assiminea modesta* Lea, drawn by W. Howe, after a camera sketch. $\times 35$.
- Fig. 10. *Assiminia modesta* Lea. e. = eye-spots, ped. = peduncle (fused eye-stalks and tentacles?). b. m. = buccal mass. The figure fails to show the relative sizes of the eye spots. The lateral spot should be the larger by one third.
- Fig. 11. One row of teeth from the radula of *Assiminea modesta* Lea. After a camera sketch, oc. 1 \times obj. 7.
- Fig. 12. Dorsal aspect of *Corambella depressa*. From a camera sketch of a formol specimen of 4 mm., oc. 1 \times ob. 3.
- Fig. 13. Ventral aspect of *Corambella depressa* from a camera sketch of a specimen cleared in cedar oil, oc. 1 \times obj. 3. m. = mouth, o. p. = oral palps, s. e. = sexual extrovert, f. gl. = foot glands (?), a. pap. = anal papilla, g. pl. = gill-plates, c. = cardiac vessel.
- Fig. 14.¹ Ventral aspect of *Corambella depressa* resting on under surface of a slide, from a camera sketch, oc. 1 \times obj. 3. rh. = rhinophore, rh. sh. = rhinophore sheath.
- Fig. 15. One row of teeth from the radula of *Corambella depressa*. After a camera sketch, oc. 1. \times oil-immersion $\frac{1}{2}$.

¹ NOTE. Opportunity for further observation since the plate was made has shown that this figure is not a successful representation of the living animal in its normal state. The notaeum is represented as too ample and much too convex, the rhinophores (which usually turn backward in a graceful sweep) as too stout, the foot in creeping extends behind the mantle, while the oral palps are turned slightly forward. Neither the characteristic vermiform lines of the notaeum nor a large irregularly trilobed blotch which often appears near the middle of the foot is shown. The general outline is usually either almost rectangular or broadest posteriorly and often very slightly emarginate there.



No. 8.—*The Blood Vessels of the Heart in Carcharias, Raja, and Amia.*¹

By G. H. PARKER AND FREDERICA K. DAVIS,

Cambridge, Mass.

With three plates.

Introduction.

In mammals the blood vessels of the heart are usually disposed in the following way: A right and a left coronary artery take their origins from the base of the aorta and are distributed, in the main, to the ventricular and auricular walls of their respective sides. The blood from these arteries is collected by a set of superficial veins arranged in three systems: a right, a left, and a median one. The right system is represented by the right or small coronary vein; the median by the middle cardiac vein; the left by the left or great coronary vein and the posterior cardiac veins. All these veins enter the coronary sinus, which in turn enters the right auricle. In addition to these superficial veins, the walls of the heart contain the numerous but small deep-seated vessels of Thebesius which, according to Langer ('81), open from the ventricles and auricles into a system of fine branches that connect with the coronary arteries and veins by means of capillaries. In the case of the veins, but not of the arteries, these connections may be by vessels larger than capillaries, as demonstrated by Pratt ('98, p. 92).

The extent to which the blood vessels characteristic of the mammalian heart occur in the lower vertebrates has never been fully ascertained. Presumably the most primitive conditions occur among fishes, and we have, therefore, undertaken the study of these vessels in three easily accessible species: *Raja erinacea* Mitchill, *Carcharias littoralis* Mitchill, and *Amia calva* Linn. The work on *Raja* and *Amia* was done in the Zoological laboratory of Radcliffe college at Cambridge; that on *Carcharias* was carried on at the laboratory of the United States fish commission at Woods Hole, Mass., and we take this opportunity of expressing our thanks to

¹ Contributions from the Zoological laboratory of the Museum of comparative zoology at Harvard college. E. L. Mark, Director. No. 101.

the Director of the laboratory, Prof. H. C. Bumpus, for much kind assistance in connection with this portion of the research.

Coronary Arteries.

The coronary arteries and the vessels with which they are directly connected reach a higher degree of complexity in the elasmobranchs than in any other group of fishes, and consequently questions of terminology have arisen chiefly in connection with these forms. The system which we shall adopt is, in the main, an expansion of that employed by T. J. Parker ('84 and '87) in his contributions to this subject, and its components may be briefly defined in the following way: The irregular, longitudinal artery by which the ventral ends of some or all of the efferent branchial arteries of a given side are brought into communication may be called the lateral hypobranchial artery (Pl. 1, fig. 1, *h'brn. l.*). The arteries which leave the lateral hypobranchials on their median sides and, after more or less transverse courses, unite with one another in the median plane may be termed the commissural arteries (*coms. iv-v*). The longitudinal median trunk produced by the union of the commissural arteries may be designated the median hypobranchial artery (*h'brn. m.*). From the posterior end of the median hypobranchial, the coronary arteries (*cor. v.*) pass off to the heart. In the skates, there are in addition posterior coronary arteries (Pl. 1, fig. 2, *cor.p.s.*). These arise from a vessel which is a branch of the subclavian artery and which from its proximity to the coracoid portion of the pectoral girdle may be called the coracoid artery (*cc'id.*). The coracoid artery, besides giving rise to the posterior coronary and certain small branches to the neighboring muscles, may anastomose with either the median or the lateral hypobranchial artery.

The terms defined in the preceding paragraph agree in general with those used by Parker ('87), except in the case of the hypobranchials. This author, to whom we are indebted for the name of these vessels, figured and described them as branches from the subclavians. After leaving the subclavians they give rise to the posterior coronaries, and, according to him, either they retain lateral positions, as in the skate, where they extend anteriorly to connect with the ventral ends of the efferent branchials of either side, or they unite in the median plane and give rise to a single longitu-

nal vessel following the course of the ventral aorta. That the lateral and median vessels are not homologous, as is implied in Parker's account, is seen from the fact that in *Mustelus*, as Parker himself ('87, p. 697, Pl. 34, fig. 1) has shown, both sets of vessels may be present. We have, therefore, given them distinguishing names: median and lateral hypobranchials. Moreover, neither of these vessels can be properly considered a dependency of the subclavian, for the branch which leaves that artery, and which Parker regarded as their root, may be connected with them, as Hyrtl ('58, p. 17, Taf. 2) has shown, by only a relatively small vessel. The union, then, is not in the nature of a continuous trunk, but an anastomosis, and the vessel posterior to this union must be considered in the light of an independent artery. This we have called the coracoid artery.

In *Carcharias littoralis* the lateral hypobranchial artery (Pl. 1, fig. 1, *h'brn. l.*) is a vessel irregular in its course but always connected with the efferent branchials of the second, third, fourth, and fifth visceral arches (II-V).¹ It may extend to meet those of the sixth arch (VI), but when this occurs, the prolongation is usually on one side of the animal only, and the system as a whole is unsymmetrical.

Lateral hypobranchials, essentially similar to those in *Carcharias*, occur in *Zygaena malleus* and in *Mustelus stellatus* according to the figures given by Hyrtl ('72, Taf. 3, fig. 2, and Taf. 2, fig. 2) and in *Mustelus antarcticus* as figured by Parker ('87, Pl. 34, fig. 1). In these three species the vessels are figured as extending from the second to the sixth arch.

Carcharias possesses two or at most three pairs of commissural arteries. The most anterior pair lies in the grooves between the second and third insertions of the coracobranchial muscles (Pl. 1, fig. 1, *cc'o brn. 2* and *3*) and parallel with the efferent arteries going to the fourth visceral arches. We have, therefore, called these vessels the commissural arteries of the fourth arch or more briefly the fourth commissural arteries (*coms. iv*). In a corresponding way, fifth commissural arteries (*coms. v*) can be distinguished. The fourth and fifth arteries were found in all the

¹ In numbering the visceral arches we have followed the scheme laid down by Gegenbaur ('98, p. 457), in which the first visceral arch is represented by the upper and lower jaws, the second by the hyoid arch, the third by the first branchial arch, the fourth by the second branchial arch, etc.

specimens we dissected, while a sixth was less constant. When present, this last was connected with either the anterior or the posterior efferent arteries of the sixth arch or with both. Occasionally, as shown in the figure, it failed to reach the vessels of any arch. The variations in this respect were often unsymmetrical.

Judging from the descriptions and figures given by various authors, commissural arteries of the fourth arch occur in all sharks.¹ The only exception to this statement is the observation made by de Blainville ('11, p. 117) that in *Squalus pelegrinus* the coronary arteries probably come from the efferent arteries of the posterior arch, presumably the sixth; but as the origin of these vessels was not exactly determined, this may have been a mistaken surmise. From the evidence of previous figures and descriptions, commissural arteries of the fifth arch occur in *Mustelus* (Hyrtl, '72, p. 271; Parker, '87, p. 697), in *Zygaena* (Hyrtl, '72, p. 271), and in *Scyllium* (Hyrtl, '72, p. 267; Marshall and Hurst, '92, p. 242), where, however, they have been called by Hyrtl, *Arteria nutriens recurrens* (branchialis). Commissural arteries of the sixth arch, such as occasionally occur in *Carcharias*, have been figured only in *Zygaena* by Hyrtl ('72, Tab. 3, fig. 2).

The median hypobranchial artery (Pl. 1, fig. 1, *h'brn. m.*) in *Carcharias* is formed on the ventral side of the ventral aorta by the union of the right and left fourth commissural arteries. This vessel has no anterior branch such as Hyrtl ('72, p. 271) has described in *Zygaena* under the name of *Arteria thyreoidea impar*, but extends entirely in a posterior direction, and, after giving off what Hyrtl ('72, p. 269) has called the epigastric branch (*e'ga.*), becomes the ventral coronary (*cor. v.*). A dorsal coronary artery (Pl. 2, fig. 4, *cor. d.*) is formed on the dorsal side of the ventral aorta by a corresponding union of the right and left fifth commissural arteries, supplemented by the sixth when they are present. The trunk thus formed lies so near the heart that it may be called the dorsal coronary artery (*cor. d.*), though it might without impropriety be regarded as in part a median hypobranchial.

Much the same condition as that found in *Carcharias* has been described for *Zygaena* (Hyrtl, '72, p. 271, Taf. 3, fig. 2) and *Mustelus* (Parker, '87, Pl. 34, fig. 2), except that in these fishes the

¹They are found in *Scyllium* according to Hyrtl ('72, p. 267) and to Marshall and Hurst ('92, p. 242); in *Mustelus* according to Hyrtl ('72, p. 271) and Parker ('87, p. 697); and in *Squatina*, *Acanthias*, and *Zygaena* according to Hyrtl ('72, p. 268-269 and 271).

ventral vessel is formed from the fourth and fifth commissural arteries instead of from the fourth only, and the dorsal vessel is not definitely shown to be present. In *Scyllium*, however, according to Hyrtl ('72, p. 267) a dorsal vessel is present; but it arises from the fourth commissural arteries which also give rise to *paired* ventral vessels. In *Acanthias* and *Squatina* Hyrtl ('72, p. 269) describes only ventral vessels; these are, however, paired and only the right one extends to the ventricle.

In *Carcharias* the epigastric artery is distributed to the muscles which surround the pericardial space. According to Hyrtl ('72, p. 269 and 271) this artery also occurs in *Acanthias* and *Zygaena*. It has been identified in *Squatina* (Hyrtl, '72, p. 269) and in *Mustelus* (Parker, '87, p. 697), in both of which it anastomoses with what we have called the coracoid artery, thus establishing connections between the subclavian and the median hypobranchial systems.

The ventral coronary artery (Pl. 1, fig. 1, *cor. v.*) in *Carcharias* divides into three vessels, a median, a right, and a left, and is thus distributed over the ventral surface of the ventricle. The dorsal coronary (Pl. 2, fig. 4, *cor. d.*) also divides into three branches, one of which goes to the right side of the ventricle and to the auricle, another to the left side of the ventricle, and a third by passing around the conus to the left anastomoses with branches of the ventral coronary.

The coronary arteries in sharks have not heretofore been described in detail except in the case of *Selache*, in which, according to the careful account given by Pavesi ('74, p. 67, 68), the plan of distribution coincides almost exactly with that found in *Carcharias*.

As in the cases of other sharks, *Carcharias* possesses no posterior coronary arteries.

In *Raja erinacea* the lateral hypobranchial arteries (Pl. 1, fig. 2, *h'brn. l.*) show great diversity, extending in some instances over the branchial region from the second to the sixth arch, while in others they are restricted to the middle portion of this region. Any efferent branchial artery of any arch between the second and sixth may, or may not, connect with the lateral hypobranchial; connection is, however, the rule with vessels near the middle of the series and the exception with those near the anterior and posterior extremes. So far as these connections were concerned, none of the specimens examined by us were bilaterally symmetrical.

The lateral hypobranchial artery of the skate was early described by Monro (1785, p. 16, Tab. 1, figs. 4, 5), who stated that it was connected with all the efferent branchial arteries. Hyrtl ('58, p. 16) described it in *Raja clavata* as coming exclusively from the vessels of the second branchial cleft, i. e., the cleft between the third and fourth visceral arches; and Parker ('84, p. 61) figured it in *Raja nasuta* as connected with the efferent arteries of this cleft and the next posterior. In our experience these differences are quite as likely to be individual variations as to be of specific importance.

The commissural arteries in *Raja erinacea* are of two kinds, dorsal and ventral, of which only the dorsal correspond to the commissurals in *Carcharias*. These dorsal vessels pass through the coracobranchial muscle, either in company with the afferent branchial arteries of the fourth arch (Pl. 1, fig. 2, *coms. d. iv.*), in which case they correspond to the fourth commissural arteries in *Carcharias*, or in company with those of the fifth arch, thus representing the fifth commissurals. A vessel (*coms. d. vi.*) whose root may possibly represent the sixth commissural is usually present, but has never been observed to be connected with the lateral hypobranchial system. In no skate examined by us were both the fourth and fifth commissural arteries present, but notwithstanding this fact the two sets of vessels were so constant in their relation to afferent branchials that their serial homology cannot be doubted.

The ventral commissural arteries in the skate (Pl. 1, fig. 2, *coms. v.*) spring from the lateral hypobranchials and pass mediad between the coracobranchial and the coracohyoid muscles, i. e., lie ventral to the coracobranchial muscle instead of dorsal to it. They may be entirely absent and when present are usually unilateral, though a trace of a companion vessel may sometimes be present (Fig. 2). They occurred in six of the twelve specimens examined by us; in four they were unilateral and associated with dorsal commissural arteries on the same side; in a fifth case the ventral artery was unilateral but unaccompanied by a dorsal vessel on the same side; and in the sixth instance the arteries were bilateral and associated with but one dorsal artery. Dorsal and ventral arteries, when both are present on a given side, unite near the ventral aorta (Fig 2).

Heretofore dorsal and ventral commissural arteries have not been distinguished, but when the figures and descriptions of the earlier

authors are compared it must be admitted that both sets of arteries have been previously observed. Thus in *Raja clavata*, Hyrtl ('58, p. 16) described and figured the commissural arteries as lying between the coracobranchial and coracohyoid muscles; hence they correspond to what we have called ventral commissurals; and the same may be said of the commissural arteries figured in a species of skate by Martin ('94, Fig. 7). Dorsal commissurals have been figured by Parker ('84, p. 62, Fig. 20) in *Raja nasuta* and by Monro (1785, p. 16, Tab. 1, fig. 4) in the species of skate described by him. In *Raja nasuta* they are the fifth commissurals and in the species figured by Monro they are double and represent commissurals of the fourth as well as of the fifth arch.

The right and left commissural arteries in *Raja erinacea* converge on the root of the ventral aorta, where they may anastomose, as in *Raja clavata* (Hyrtl, '58, p. 16), or remain unconnected. From each commissural artery a coronary artery extends over the bulbus to be distributed to the ventricle. The left coronary (Pl. 1, fig. 2, *cor. s.*) is larger than the right (*cor. dx.*) and is distributed in the main to the ventral surface of the ventricle; the right extends to the dorsal surface of the bulb and ventricle and to the auricle. This plan of distribution has already been observed in other species (*Raja clavata*, Hyrtl, '58, p. 16; *Raja* sp.?, Martin, '94, p. 25; *Torpedo* sp.?, Hyrtl, '58, p. 3).

From the coracoid arteries in *Raja erinacea* posterior coronary arteries (Pl. 1, fig. 2, *cor.p.s.*) may extend over the ventral face of the venous sinus to be distributed to the dorsal face of the ventricle. These vessels may be unilateral (Fig. 2) or paired (Pl. 2, fig. 5). Similar vessels have been described and figured in *Raja clavata* (Hyrtl, '58, p. 17) and *Raja nasuta* (Parker, '84, p. 61).

The coracoid arteries in *Raja erinacea* may give off branches which anastomose with what we have supposed may represent the sixth commissural arteries (Pl. 1, fig. 2, *coms. d. vi.*), a condition similar to what has already been found in other skates by Monro (1785, Tab. 1, fig. 4), Hyrtl ('58, Taf. 2), and Parker ('84, p. 62, Fig. 20).

In *Amia calva* no trace of lateral hypobranchials was discoverable. The arteries which supply blood to the coronaries come from the fourth visceral arches, and hence correspond to the fourth commissural arteries (Pl. 2, fig. 3, *coms. iv.*). These unite in the

median line on the ventral side of the ventral aorta and give rise to a median hypobranchial artery (*h'brn. m.*). This extends posteriorly, giving off a large epigastric branch (*e'ga.*), and then divides to give rise to a ring vessel surrounding the aorta and to two coronary arteries, one dorsal (Pl. 2, fig. 6, *cor. d.*) and the other ventral (Pl. 2, fig. 3, *cor. v.*). These extend posteriorly over the bulb to be distributed eventually to the respective faces of the ventricle. Each coronary shows evidence of division into right and left branches.

Judging from the figures and descriptions of various authors, the coronary arteries of most teleostomes conform to the plan in *Amia*.¹ Probably in all the higher fishes the vessels leading from the gills towards the heart are the fourth pair of commissural arteries. Stannius ('46, p. 101), however, described these vessels in the sturgeon as coming from the third branchial arch and hence corresponding to the fifth commissurals; but this is probably a mistake, for, according to Hyrtl ('55, p. 11), the vessels in the sturgeon come from the fourth visceral arches as in other higher fishes. The cod has been described by Jourdain ('67, p. 192) as receiving its coronary supply from the third branchial arch, while Parker ('84, p. 117) figures it as coming from the fifth. The vessel in the cod, however, is so small and the ventral ends of the efferent branchials are so crowded that the exact connections are rather matters of interpretation than observation. Since the sturgeon and the cod seem to be the only recorded exceptions to the general rule, and since these, as exceptions, are of doubtful value, it may well be that in all teleostomes the vessels that leave the gills for the heart come from the fourth visceral arches and represent fourth commissural arteries.

Both the right and the left fourth commissural arteries are well developed in *Amia*, and the same is presumably true of the sturgeon (Hyrtl, '55, p. 11) and of the pike (Müller, '41, p. 198). In *Scomber* and *Pelamis* the right artery is said (Hyrtl, '55, p. 11)

¹The chief exception to this statement is to be found in *Orthogoriscus mola*, as described by Milne-Edwards ('58, p. 341). According to this author, *O. mola* has lateral hypobranchial arteries connecting the efferent branchials of the first, second, and third branchial arches. It has a ventral median hypobranchial formed from the fourth pair of commissural arteries and giving rise to a ventral coronary artery. It further has a dorsal median hypobranchial formed from the sixth commissural arteries and giving rise to a dorsal coronary artery. This description corresponds so well with what is found in some elasmobranchs, and is so unlike what is known to occur in other teleostomes that we have been tempted to call its accuracy into question. Unfortunately, we have had no material by which to test this question.

to be noticeably smaller than the left. Only the left artery is reported present in the following fishes: *Perca fluviatilis* (Cuvier et Valenciennes, '28, p. 380, Pl. 7, fig. 1), *Salmo* (Agassiz et Vogt, '45, p. 125; Hyrtl, '55, p. 11; Martin, '94, p. 20), and (according to Hyrtl, '55, p. 11) *Lotu vulgaris*, *Lucioperca sandra*, *Silurus glanis*, *Astro zingel*, *Labrax lupus*, *Zeus faber*, *Xiphius gladius* and the cyprenoids *Aspius*, *Squalius*, *Abramis*, and *Leuciscus*. Martin ('94, p. 16), however, states that it is the right artery which is present in *Abramis* and the roach (*Leuciscus*) as well as in the carp. In *Ceratodus* it is also, according to Spencer ('93, p. 8), the right artery that is present, the left being entirely unrepresented. It is, therefore, probable that in many teleostomes the commissural portion of the coronary system is unilaterally developed and that in some cases it is dextral, in others sinistral.

The Superficial Veins of the Heart.

These veins, often included under the general name of coronary veins, are relatively inconspicuous as compared with the coronary arteries and have received correspondingly less attention. In *Carcharias littoralis* they open into the venous sinus (Pl. 3, fig. 7, *sn. vn.*) by two orifices, one to the right and the other to the left of the sinu-auricular aperture (*ap.*). The right orifice leads into the right vein (*vn. cor. dx.*), which passes ventrally in the coronary sulcus and is finally distributed in the main to the dorsal wall of the bulbus, though a few small branches also pass to the right side of the ventricle (Fig. 10, *vn. cor. dx.*). This corresponds very closely to the right or small coronary vein in mammals. The left orifice is the opening for three veins, the largest of which (Fig. 7, *vn. cor. s.*) passes to the left and is distributed to the left and ventral aspects of the ventricle as well as to the ventral side of the bulbus (Fig. 10, *vn. cor. s.*). This corresponds closely to the left or great coronary vein in mammals. The two remaining veins (Fig. 7, *vn. crd. m.*) are small and are restricted to the dorsal surface of the ventricle. They correspond collectively to the cardiac veins in mammals.

In the sharks reported upon by previous investigators the superficial veins always open into the venous sinus near the sinu-auricular aperture. In *Squalus* (de Blainville, '11, p. 117) and *Scyllium* (Röse, '90, p. 34) there are said to be two such openings, and this is

probably also true of *Mustelus* (Parker, '87, p. 720), but in *Selache* (Pavesi, '74, p. 62) and *Acanthias* (Röse, '90, p. 34) the veins are described as uniting and entering the sinus by a single opening. Right and left systems have been identified in *Mustelus* (Parker, '87, p. 720) and in *Selache* (Pavesi, '74, p. 68), and in the latter, as in *Carcharias*, the left system is more fully developed than the right.

In *Raja erinacea* the right coronary vein is represented by two vessels (Pl. 3, fig. 8, *vn. cor. dx.*), which have separate openings into the venous sinus, one of which lies more to the right than the other. The vein on the extreme right has two principal branches, the first one to the dorsal surface of the cone and the second to the ventral surface of this organ and of the ventricle (Fig. 11, *vn. cor. dx.*). This second branch passes through the right side of the groove which separates ventricle from cone. The vein to the left also has two principal branches, one of which extends over the dorsal side of the cone (Fig. 8) and the other passes over the ventricle to the left of the cone to be distributed finally to the ventral face of the ventricle (Fig. 11). In passing from their ventral areas of distribution to their dorsal openings into the venous sinus both these vessels lie to the right of the connection between auricle and ventricle, i. e., in what corresponds to the right portion of the coronary sulcus. We have, therefore, regarded them as together equivalent to the right coronary vein.

The left coronary vein (Figs. 8 and 11, *vn. cor. s.*) is a single main trunk from the left portion of the ventricle and enters the venous sinus by a single opening at a considerable distance to the left of the sinu-auricular aperture (*ap.*).

The right and the left coronary veins are distributed to the whole of the ventral face and the outer edges of the dorsal face of the ventricle. The central portion of the dorsal face is covered with a system of veins (Fig. 8, *vn. crd. m.*) which enter for the most part into a transverse trunk extending parallel to the posterior edge of the venous sinus. From this trunk small vessels pass across to the venous sinus into whose cavity they open. This system of vessels corresponds very closely to the cardiac veins of mammals.

The openings of what are presumably the right and the left coronary veins in a skate were described and figured by Monro (1785, p. 18, Tab. 3, 37). The same was shown in *Raja rubus* by Tiede-

mann ('09, p. 9, Tab. 1, fig. 2), who also figured the openings of six small vessels belonging to the cardiac veins.

In *Amia calva* the superficial veins of the heart (Pl. 3, fig. 9) open into the venous sinus by a single orifice which lies posterior and slightly to the right of the sinu-auricular aperture (*ap.*). From this opening two veins, the right (*vn. cor. dx.*) and the left (*vn. cor. s.*) coronary veins, encircle the heart at the level of the coronary sulcus and anastomose so freely on the ventral side (Fig. 12) that a ring vessel is established. From the right coronary vein (Fig. 9, *vn. cor. dx.*) two branches are given off, one anteriorly to the right side of the cone, and the other posteriorly to the same side of the ventricle. From the left coronary vein (*vn. cor. s.*) a corresponding pair of branches is given off; that to the cone, however, is small and more ventral (Fig. 12) in position than its fellow of the opposite side. From the ventral anastomosis of the coronary veins a single vein extends over the median ventral surface of the ventricle (Fig. 12). This probably represents a branch from the left coronary vein. The coronary veins of higher fishes have generally escaped attention. Röse ('90, p. 35) mentions them as present in *Pimelodus catus* and *Tetrodon physa*, but absent from the eel; and Martin ('94, p. 21) states that in the salmon the right coronary vein only is present and this opens into the auricle. That there is a unilateral condition of the coronary veins as well as of the arteries in the higher fishes is not impossible.

Vessels of Thebesius.

The vessels of Thebesius seem heretofore never to have been sought for in the hearts of fishes. We have endeavored to ascertain whether they were present in the three species which we have studied.

On inflating the left coronary vein of a fresh heart of *Charcharias littoralis* by means of a blowpipe, the auricle was gradually distended with air. As the entrance of air into the auricle through the sinu-auricular opening was carefully guarded against, such air as found its way into the heart must have come through some other aperture. If a heart whose auricle is distended with water be inflated as described above, bubbles will be seen forming on the inside of the left wall, and if the opposite wall be removed, these

bubbles can be seen coming off freely from the inner surface of the uninjured wall. Similar experiments on the right coronary vein gave only negative results, and from neither the right nor the left vein could bubbling be produced from the inner surface of the ventricle.

As this experiment can be successfully carried out with only a slight pressure of air, there is no reason to suppose that vessels were ruptured, and we believe we are justified in concluding that the left coronary veins have connections which open freely on the inner surface of the left auricular wall. These connections can be none other than the vessels of Thebesius. Attempts to blow from the inside of the auricle through to the left coronary vein always failed, doubtless because of the impediment offered by the spongy nature of the auricular wall.

Experiments of a similar character carried out on the coronary arteries resulted in the production of small bubbles on the inside of the left auricular wall. This, however, was accomplished only after very vigorous blowing and consequently demonstrates that the connections between the coronary arteries and the veins of Thebesius are much more restricted than those between the coronary veins and these vessels, a condition already observed by Pratt ('98) in mammals.

On inflating either the right or the left coronary vein of *Raja erinacea* with air, bubbling could also be demonstrated from the uninjured inner surface of the auricle, but no bubbling was ever observed from the inner surface of the ventricle.

If the single opening of the coronary veins in *Amia calva* be inflated, bubbling takes place from the inner surface of the ventricle as well as of the auricle. This fish was the most satisfactory of the three species for the demonstration of the vessels of Thebesius.

These experiments, in our opinion, show that the hearts of fishes possess veins of Thebesius which open into the ventricles as well as into the auricles and which connect more freely with the coronary veins than with the coronary arteries.

Conclusions.

When the blood vessels of the heart in fishes are compared with those in mammals, the most noteworthy feature is the striking simi-

larity between the two sets of structures. Vessels of Thebesius may open into the single auricle and ventricle of a fish as they open into the paired auricles and ventricles of a mammal; and their freer communication with the coronary veins than with the coronary arteries in the fish recalls the condition found in mammals. Morphologically the vessels of Thebesius in fishes seem to correspond exactly to those in mammals.

The superficial veins of the heart in fishes are also much like those in mammals. A right, a left, and a median system can be distinguished, and in *Carcharias* the vessels representing these are almost identical with those in the mammalian heart. In only one important respect do the superficial veins in fishes differ from those in mammals; in fishes these veins open into the venous sinus, in mammals into the right auricle. When, however, it is remembered that the venous sinus in mammals becomes incorporated in the right auricle this supposed difference disappears. There is then no reason for supposing that the veins of the mammalian heart are not homologous with those in the heart of the fish.

The coronary arteries in fishes show less resemblance to those in mammals than has been noticed between the other classes of vessels, and this is particularly true of the way in which the coronary arteries originate. These arteries in mammals arise from the base of the aortic arch very near the heart; in fishes they come from the efferent branchial arteries at places that would correspond to positions well towards the dorsal side of the aortic arch of a mammal. The fact that the ventral aorta of a fish carries impure blood and the corresponding vessels in a mammal pure blood, is a sufficient physiological reason for this difference, but it leaves the question of the homology of these parts entirely open. Have the coronary arteries of mammals been derived from those of fishes or are they a new system of vessels? The supposed absence of coronary arteries from the heart of amphibians has been urged in favor of the latter opinion, but Martin's ('94, p. 59-60) statement that in the tadpole a system of coronary arteries essentially like that in the fish is replaced towards the close of larval life by other coronary arteries is in reality almost the first piece of positive evidence bearing on this question. While this evidence is opposed to the homology of the coronary arteries of higher and lower vertebrates, it must not be forgotten that the vessels of Thebesius and the coronary veins of the higher and lower forms show every evidence

of being homologous, and since the arteries constitute an integral part of this system, it seems improbable that they alone should have undergone such fundamental replacements as is implied by Martin's observations on the frog. Possibly the condition in the Amphibia is to be explained on the basis of coenogenetic changes. However this may be, the whole question of the homology of the coronary arteries in higher and lower vertebrates seems to us to demand much more extensive comparative study, both anatomical and embryological, than has thus far been accorded to it, before a final answer can be reached.

Summary.

1. Vessels of Thebesius have been found to open into the auricle of *Carcharias*, and of *Raja* and into the auricles and ventricles of *Amia*. These vessels communicate more freely with the coronary veins than with the coronary arteries. They are homologous with the similarly named vessels in mammals.

2. The superficial veins of the heart in *Amia*, and particularly in *Raja* and in *Carcharias*, are arranged in three groups corresponding to the right coronary vein, the left coronary vein, and the middle cardiac vein of mammals. These three groups of veins in fishes open into the venous sinus and thus agree in this respect with the similarly named mammalian veins which open into the right auricle into which the venous sinus has been incorporated. The above mentioned superficial veins of the fish's heart are homologous with those in the mammal's heart.

3. The ventral ends of the efferent branchial arteries in fishes may be connected by a lateral hypobranchial artery. From this, commissural arteries may pass towards the median plane; these may be either dorsal or ventral as in *Raja*, and the dorsal ones may be serially arranged corresponding to the fourth, the fifth, and possibly the sixth visceral arches, as in *Carcharias* and *Raja*. The union of the right and left commissurals gives rise to a median hypobranchial from which coronary arteries (anterior) are given off. These coronary arteries differ from those in mammals chiefly in the remoteness of their point of origin. This, however, does not necessarily preclude homologizing them with the coronary arteries in mammals.

Posterior coronary arteries were found only in *Raja* and have no homologues in mammals.

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EXPLANATION OF PLATES.

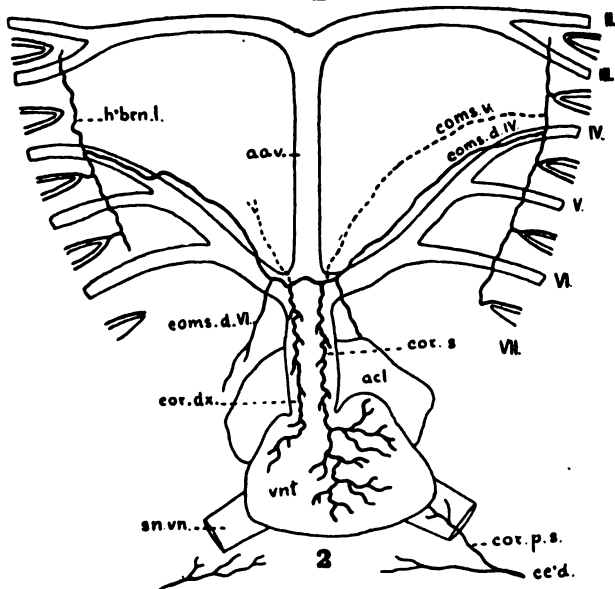
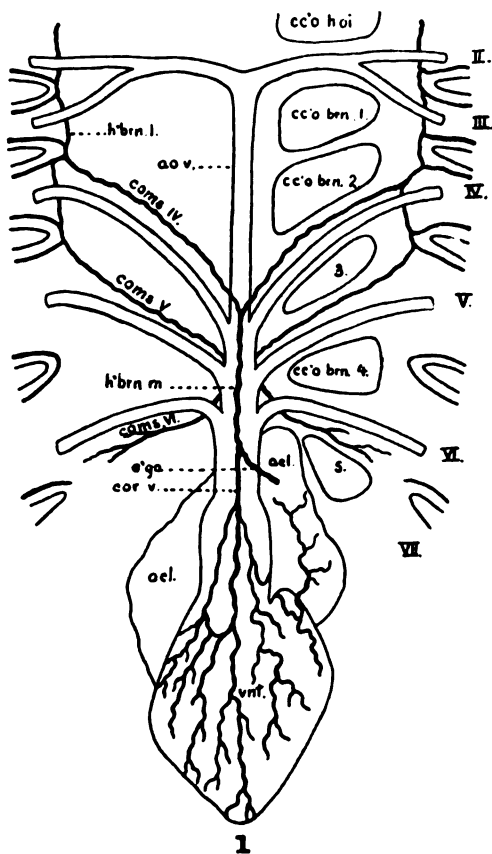
ABBREVIATIONS.

<i>acl.</i>	Auricle.
<i>ao. v.</i>	Ventral aorta.
<i>ap.</i>	Auriculo-ventricular aperture.
<i>cc'd.</i>	Coracoid artery.
<i>cc'o brn. 1-5.</i>	Insertions of coracobranchial muscle.
<i>cc'o. hoi.</i>	Insertion of coracohyoid muscle.
<i>coms. iv-vi.</i>	Commissural arteries of iv-vi visceral arches.
<i>coms. d. iv-vi.</i>	Dorsal commissural artery of the iv-vi visceral arches.
<i>coms. v.</i>	Ventral commissural artery.
<i>cor. d.</i>	Dorsal coronary artery.
<i>cor. dx.</i>	Right coronary artery.
<i>cor. p. dx.</i>	Right posterior coronary artery.
<i>cor. p. s.</i>	Left posterior coronary artery.
<i>cor. s.</i>	Left coronary artery.
<i>cor. v.</i>	Ventral coronary artery.
<i>e'ga.</i>	Epigastric artery.
<i>h'brn. l.</i>	Lateral hypobranchial artery.
<i>h'brn. m.</i>	Median hypobranchial artery.
<i>sn. vn.</i>	Venous sinus.
<i>vn. cor. d.</i>	Right coronary vein.
<i>vn. cor. s.</i>	Left coronary vein.
<i>vn. crd. m.</i>	Median cardiac vein.
<i>vnt.</i>	Ventricle.
I-VII.	Visceral arches I-VII.

The figures are drawn from actual dissection and are about natural size. Blood vessels covered by other structures are often indicated by dotted lines.

PLATE 2.

- Fig. 3. Ventral view of the heart and the adjacent vessels in *Amia calva*.
Fig. 4. Dorsal view of the heart and attached vessels of *Carcharias*. The auricle has been removed.
Fig. 5. Dorsal view of the heart of *Raja* with the venous sinus laid open and the posterior coronary arteries shown.
Fig. 6. Dorsal view of the heart and the coronary artery in *Amia*. The auricle has been removed.



п

No. 9. — *The Occurrence of Fossils in the Roxbury Conglomerate*

BY HENRY T. BURR AND ROBERT E. BURKE.

THE age of the Boston Basin sediments has long been a matter for controversy. Two types of rock make up the mass of the section, a thick series of heavy conglomerates, and a series of compact, flinty slates. The former are known as the Roxbury conglomerates, and are usually assumed to be of the same age throughout. The slates are generally similar in character, but are now believed to represent at least two widely different horizons. The conglomerates and much the greater portion of the slates are remarkably barren of fossils. In 1856 *Paradoxides harlani* Green was reported from the slates near Hayward's Creek, Braintree, Rogers, '56, pp. 27-29, 40-41. This discovery established the age of that portion of the slates as Cambrian. As the greater part of the slates in the Basin resemble those of Braintree, the whole series was regarded as of the same age. Within recent years Lower Cambrian fossils have been found in the impure limestone at Nahant, Foerste, '89, pp. 261-263, and at Mill Cove, Weymouth, Grabau, '98, also Burr, 1900.

In some parts of the Basin, at least, the conglomerates appear to underlie the slates; hence they, too, were held to be of Cambrian age. The conglomerates are largely made up of fragments which appear to have been derived from the complex of granitic rocks to the south, Crosby, '89, p. 6. The granite, then, is older than the conglomerate. On the supposition that the conglomerate is below the slate, it is necessary to regard the granite as older than the slate, also. But the granite, as is now known, is intrusive into the slates of Braintree, Wadsworth, '83, p. 27; also Crosby, '89, p. 5, and is, therefore, later than that portion of the Cambrian series. The conglomerates, then, not only overlies the Middle Cambrian slates, but are separated from them by a great period of igneous action, and an interval long enough to allow the forces of erosion to penetrate deep into the granite mass. It is, therefore, no longer necessary to regard the conglomerates and associated slates as of Cambrian age. In the absence of positive evidence to the contrary, however, they are still held to be Cambrian by many observers, and are so mapped by Walcott in his correlation papers, Walcott, '91, p. 268, and map, p. 358.

Of late years the opinion has been gaining ground that the conglomerates, at least, should be referred to the Carboniferous. This belief is based largely upon the strong lithological resemblance between the Boston Basin series and the Carboniferous conglomerates of the neighboring Norfolk County and Narragansett Basins. The argument from analogy is not strictly valid, for it is quite possible that very similar conglomerates might be formed at widely different horizons, particularly where the sources of supply remain the same. In fact, as has been pointed out, our glacial material, if worked over by the sea, would yield a deposit essentially like the Roxbury conglomerate.

Until recently the idea of the Carboniferous age of these sediments has been practically unsupported by fossil evidence. Some years ago Mr. J. B. Woodworth found, in the conglomerate near Franklin Park, a fragment which he regarded as a portion of a fossil plant, similar to forms occurring in the sandstones of the Narragansett Basin. Not then appreciating the importance of his discovery, he did not preserve the specimen. Other observers have reported the discovery of fossils in the conglomerates and associated slates, but no identifiable forms have ever been produced.

During the past year the writers have made a careful search over a considerable portion of the area. Traces of possibly organic remains have been found in the slates and in the quartzite pebbles of the conglomerate, but none of these have had any determinative value. Recently, however, a sandy zone near the top of the conglomerates has yielded fossils of a much more satisfactory nature. These are believed to be casts and moulds of the trunks or roots of tree-like forms. They are cylindrical in form, with circular cross-sections. The largest has a maximum diameter of four and eight tenths inches. They are marked by somewhat irregular transverse wrinklins (see Plate 1), which sometimes pass entirely around the form, sometimes die out, or become united. The organic matter has entirely disappeared. The casts are composed of compact sandstone, which is indistinguishable from that of the rock in which they lie. The bedding of the sandstone is obscure, but is believed to lie at right angles with the axes of the fossils.

The species to which these forms should be referred cannot at present be determined. The genus, even, is highly problematical. The only markings which are at all characteristic are the transverse wrinklins referred to above. Quite similar wrinklins appear

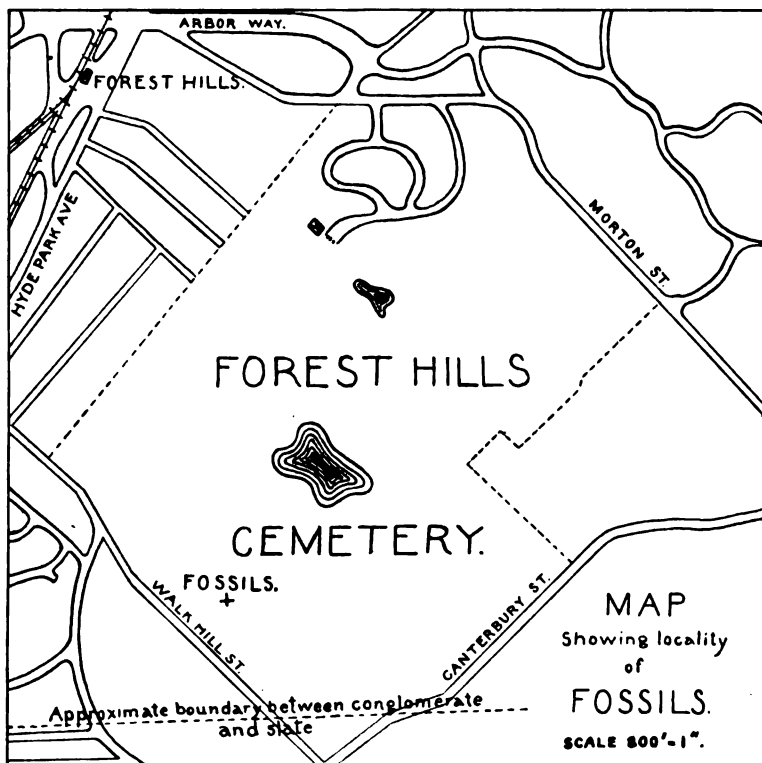
upon several species of the genus *Artisia*, particularly upon *Artisia distans*, figured by Grand'Eury in *Flore Carbonifère de la Loire*. It is quite possible that the specimens figured are related to that form. It cannot, however, be denied that such vague markings have little determinative value and may even be of mechanical origin.

While the writers are disposed to believe that these forms cannot be identified with certainty, they nevertheless feel confident that they are true fossils. The several geologists who have passed judgment upon them, have, with one exception, expressed themselves as satisfied of their organic origin. The other view is that they are due to mechanical action,—that they are akin to stylolites. It is difficult to see upon what this opinion is based. The specimens figured certainly bear little resemblance to the ordinary forms of stylolites. As generally defined, stylolites are forms produced in rocks by displacement or the development of slickensides about a portion protected by a shell or other hard capping. Such forms have characteristically slickensided surfaces, usually with strongly marked longitudinal striations, and frequently with the development of secondary minerals. The forms under consideration show no trace of longitudinal striations. The surfaces are not smooth after the manner of rubbed surfaces. There is, so far as can be seen, no development of new minerals. In short, the phenomena of slickensiding are altogether absent. Stylolites are of small size, seldom exceeding four inches in length or two in diameter. The specimens figured average about four inches in diameter, and the largest is over a foot in length, with the total length not known. There is no reason why stylolites should have a circular cross-section. It would be strange indeed if, as in this case, all the specimens found in a limited area should have this form. There seems then to be no reason whatever for thinking that the surfaces of these specimens were developed by differential movement. It should be added that stylolites usually occur in limestones or in fine-grained shales, and have never, so far as is known, been reported from coarse sandstones.

It may be suggested that these forms are concretionary. Cylindrical or rod-like concretions are not unknown, and, so far as the form is concerned, these specimens might be of such nature. If the forms are concretionary, the material of which they are made up should differ, in a determinable way, from the material of the matrix. This does not appear to be the case. In both cast and

matrix the material is a compact quartzose sandstone, without trace of lime and with but enough iron to give it a reddish tinge. Moreover, although similar sandstone is abundantly developed in portions of the conglomerate area, it nowhere shows signs of concretionary action.

No other action comes to mind as capable of producing similar forms, unless it is assumed that they may be due to jointing. But



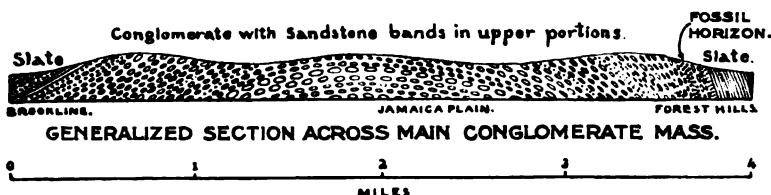
it seems extremely improbable that jointing should produce such regular forms. Moreover, the surfaces lack all the characteristic features of joints, Woodworth, '96, pp. 163-183.

All things considered, the forms are best explained as casts and moulds, and may be fairly assumed to be of organic origin.

Granting this, it is still true that these fossils do not definitely

determine the age of the conglomerate. They might have come from the Devonian or the Trias as well as from the Carboniferous. But they surely do settle the question as between Cambrian and Carboniferous. And this is and has been the point at issue.

The fossils were found in Forest Hills Cemetery, on the southern edge of the wide belt of conglomerate extending through Brookline, Roxbury and Dorchester. The field relations show that this conglomerate mass is, structurally, a broad, flat-topped anticline. The fossil horizon is, therefore, at the top of the series. The slates surround this anticline, and everywhere dip and strike conformably with the adjacent beds of the conglomerate series. It is a safe assumption that they overlie the conglomerates and are conformable with them. The accompanying section shows the



structural relation of the fossil horizon to the conglomerates and the overlying slates. The evidence from these fossils seems applicable to the whole of this conformable series.

It has not, as yet, been definitely proved that the other conglomerates of the region are of the same age as those of the central belt, although such is generally assumed to be the case. They are much alike lithologically, show the same degree of secondary alteration, and have the same apparent relations with the igneous rocks. The outcrops of slate are so scattered that it is not possible to correlate them in a satisfactory manner. It seems probable, however, that the greater part of the slate is closely associated with the conglomerate, and of approximately the same age.

It is believed, then, that the discovery of these forms serves to establish the fact that Carboniferous sediments are present in the Boston basin, and to render it probable that the greater part of the area is occupied by sediments of this age.

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No. 10.— *On a hitherto unrecognized form of blood circulation without capillaries in the organs of Vertebrata.*

By CHARLES SEDGWICK MINOT, LL. D.

THIS article is intended to draw attention to the fact that in all vertebrates there occur two types of blood-vessels with endothelial or endothelioid walls only. Vessels of both types intervene between the ends of the arteries and the veins entering the heart. The vessels of the first type are true *capillaries* and have the well-known characteristics of size and structure which are familiarly recapitulated in all text-books of histology. The vessels of the second type I propose to name "*sinusoids*," on account of their resemblance to true sinus and also to separate them clearly from genuine capillaries. A *sinusoid* differs in many important respects from a capillary, although its walls also consist merely of an endothelial (or endothelioid) layer without any strengthening additions of adventitia or media. A sinusoid is of relatively large size, and its epithelium is fitted closely against the cells of the organ in which the sinusoid is developed, and it has numerous wide and free communications with the neighboring sinusoids of the organs; the sinusoid wall follows the shape of the parenchyma of the part, while a capillary follows its own shape, and is chiefly or wholly imbedded in connective tissue. A typical sinusoid has either no or exceedingly little connective tissue between it and the adjacent parenchyma, and in those cases, where the connective tissue occurs, it is a secondary and late acquisition, and the amount remains usually, perhaps always, very small.

The development of sinusoids in the embryo, so far as known, is essentially different from that of true capillaries.

Blood sinusoids have been found to afford the main channels of the circulation in the following organs:—

1. Pronephros.
2. Mesonephros (Wolffian body).
3. Liver.
4. Heart.
5. Supra-renal capsules.
6. Parathyroid glands.
7. Carotid glands (probably).
8. Coccyeal glands.

I consider it not improbable that the circulation in the lymph glands, spleen, and in the thyroid gland of certain animals, is likewise sinusoidal, but our existing knowledge seems insufficient to decide the correctness of my supposition. As regards the thyroid gland, I will mention in passing a suggestive observation made upon sections of the organ from kittens; in these preparations the follicles are separated from one another by spaces, which are in part wide; these spaces are bounded by an endothelium, which is closely fitted against the epithelium of the gland. There seem to be no capillaries. Whether these endothelial spaces are blood channels or lymph chambers, I am unable to say at present. In the former case they are true sinusoids, as above defined.

As to whether or not the "cavernous" circulation of erectile tissue is sinusoidal or not, I am unwilling at present to express any opinion.

Finally, I am inclined to add the placenta, at least in man and the rabbit, to the list of organs with sinusoids. Such a view must be critically tested, however, before it can be accepted definitively.

This paper is a direct sequel to that which I published in volume 28 of these Proceedings—see Bibliography at the end of this article, Minot, '98.1. In the paper cited I called attention to the fact that the intertubular circulation of the pronephros and mesonephros is not capillary, but—to use the term I now propose,—sinusoidal,—*l. c.*, pp. 268–272. I will now briefly review the observations with which we are concerned, and which are, for the most part, more or less well known. The purpose is to show that the synthesis of these observations furnishes a secure generalization, namely, that there is an important type of circulation, distinct from the capillary.

A word as to the illustrations! They are none of them *strictly* accurate as to the histological details. The outlines were drawn with the camera lucida, and are nearly correct, but the details were drawn in, free hand, without any attempt at real accuracy. In every case, however, the form of the blood spaces and their endothelium have been carefully reproduced. The magnifications given are nearly but not absolutely correct.

1. **Pronephros or Head kidney.** In marsipobranchs the circulation of the pronephros, although it has not yet been very thoroughly studied, appears to be of sinusoidal type. Wilhelm Müller, '75.1, p. 113, describes the tubules as lying partly in the venous sinus,

and says "sie bestehen aus einer epithelialen Wand und einer Bindegewebshülle." He says nothing as to the vascular endothelium; it will probably be found that Müller's "Bindegewebshülle" is really endothelium, for this interpretation is certainly correct for *Petromyzon*. W. F. R. Weldon, '84.3, p. 173 and Fig. 7, speaks of the wide blood spaces "as an exceedingly rich plexus of blood-capillaries; so that during life a very considerable quantity of blood must be constantly passing between the tubules of the gland." His Fig. 7 shows the vascular endothelium following the curves of the tubules, but not in actual contact with the epithelium; this separation was probably due to imperfect preservation. Still more definite are the statements of J. W. Kirkaldy, '93.1, p. 354, in regard to *Myxine*. He says, "Examined by means of transverse sections, the head kidney is found to be in very intimate relations with the post-cardinal vein. The greater part of it is actually lodged in the vein, while the more superficial tubules are imbedded in the vascular wall, or lie free in the pericardial cavity." Unfortunately, neither in his text nor his pictures is there any record of the relation of the venous endothelium to the pronephric tubules. R. Semon, '96.1, p. 173, also points out that in *Myxine* the pronephros protrudes into a venous sinus, and his figures 6 and 7 suggest that the endothelium fits the epithelium, but he gives no definite information. Otto Maas, '97.1, p. 486, gives no precise description of the relation of the endothelium to the tubules, but his figures, 20-23, represent it as closely fitted to the epithelium of the tubules and of the ciliated funnels, precisely as in *Petromyzon*, — see Fig. 1, below.

Concerning the histological structure of the pronephros of *Petromyzon*, I have sought in vain for a modern description. [Since the completion of this manuscript, I have received Wheeler's valuable article, '99.1, in which the character of the blood spaces, the fitting of the endothelium to the pronephric tubules in *Petromyzon*, is briefly mentioned and well figured by the author. My own observations have now become hardly more than repetitions of a part of Wheeler's.] The general topography is described by older writers, as, for instance, Johannes Müller and H. Rathke. W. Müller, in his well-known monograph, '75.1, pp. 120-125, describes with characteristic clearness and accuracy the "Vorniere" of *Petromyzon fluviatilis* and *planeri*. He does not give, however, a sufficient account of the relation of the vascular channels to the pronephric tubules. The advance in technical methods since 1875 has ren-

dered it easy to obtain much better sections than Müller could have had. These better sections show many details, not yet described, and especially render clear the circulation of the organ. It has, therefore, seemed to me desirable to report my own observations, especially as regards the pronephric circulation. The accompany-

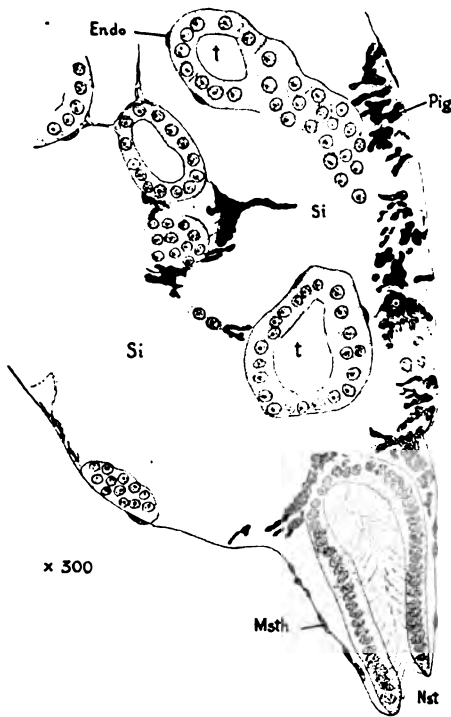


Fig. 1. *Petromyzon fluviatilis*, 37.0 mm. Transverse Series, Harvard Embryological Collection, No. 249, section 696. Ventral part of the pronephros. *Endo.*, endothelium; *Pig.*, pigment; *Si.*, blood sinusoid; *t.*, pronephric tubules; *Nst.*, nephrostome; *msth.*, mesothelium.

ing Figure 1, is from an *Ammocoetes* of 37 mm. The median plane of the embryo is to the left of the figure, which shows the natural inclination of the organ downwards and outwards; about one third of the actual section of the pronephros was drawn. The pronephros, at this stage, may be described as a huge blood chamber in which the pronephric tubules are suspended. The tubules are loosely connected together by thin strands of tissue, in which pigment cells appear; pigment cells are also numerous over the surface of the organ, but their abundance is exaggerated in the figure, owing to the lateral wall being cut obliquely. The enormous size of the blood space is very striking, and the communication between the

parts of the blood space is so free that it can hardly be described as a series of anastomosing sinusoids. In other parts of this pronephros, and in the opposite pronephros of the same section, the tubules are much less widely separated, so that the type is more

distinctly sinusoidal. The figure shows here and there the vascular endothelium, *endo*, distinctly, and always fitted against the surfaces of the tubules and intertubular tissue strands. Whether or not the endothelium covers also the inner surface of the mesothelium, I have been unable to decide, for the wall of the pronephros is exceedingly thin. In the section the sinus is gorged with blood, which is omitted from the drawing for the sake of clearness. At the lower edge of the section a nephrostome or pronephric funnel *Nst*, is cut so as to show nearly its whole length; it resembles that of *Myxine*, as figured by Semon, '96.1; it is lined by very numerous long cilia, the presence of which is roughly indicated in the drawing; the cilia from the opposite sides overlap in the middle line and they are all bent inwards. The transition from the thin mesothelium to the cylinder 'epithelium of the funnel is abrupt. In a younger stage, *Petromyzon fluviatilis* of 24.6 mm., a section through the corresponding point is very similar to that figured above,—see Harvard Embryological Collection, No. 246, sections 409–410. The morphological conditions are the same as in the older embryo, but the parts are smaller, the tubules being less in diameter, the blood spaces between them being less wide, and the ciliated funnel being both narrower and shorter. Also there are fewer pigment cells. In both these embryos, and in others of similar stages, the outside of each tubule when cut transversely shows a thin sharp line, which I consider the section of the endothelium of the blood space; here and there one finds a characteristic protuberant endothelial nucleus, Fig. 1, *endo*. I find nothing which corresponds to "einer dünnen Bindegewebshülle" described by W. Müller except this endothelium. Probably Müller and myself have seen the same covering, and have given it different interpretations. W. Müller, *l. c.*, p. 127, emphasizes the resemblance of the head kidney of the lamprey to that of the craniote anamnia, and I can fully confirm this statement, and add that it extends to the arrangement of the blood spaces in relation to the tubules. It may be added here that in an embryo of 7 mm.—see for example the Harvard Coll. No. 28, section 215—the pronephros is less than one tenth the size of that of Fig. 1; the funnel is perhaps one fifth as long; the tubules, nuclei, and blood spaces are all very much smaller than in Fig. 1. On the other hand, in older *Ammocoetes*, of 115–150 mm.—see Harvard Coll. No. 191, section 103, and No. 198, section 1438,—the nephrostomes and

tubules are still present, but the blood spaces are larger, and are much invaded and subdivided by mesenchyma, which is accompanied by pigment cells. It thus appears that the pronephros persists probably through the entire larval period of the lamprey, and that the growth of the blood spaces in size exceeds that of the tubules, so that the pronephros becomes more and more like a mere blood sack, thus reaching a morphological character which has, so far as I know, no parallel in any other class of Vertebrates. Whether or not a similar condition exists in Myxinoids is still to be determined.

Nothing can be said concerning the pronephric circulation of Elasmobranchs, since the organ is rudimentary, and even during early embryonic life is represented by a transitory anlage only.

In all the remaining fishes (teleostomes) the organ is well developed, at least in embryonic and larval stages, and it sometimes persists in the adult. I have before pointed out, Minot, '98.1, pp. 271-272, the sinusoid circulation, as it may be observed in the teleosts, *Ameiurus* and *Batrachus*, and in the ganoid *Amia*. Of this last, Fig. 2 exhibits the appearance in an embryo of 10 mm.

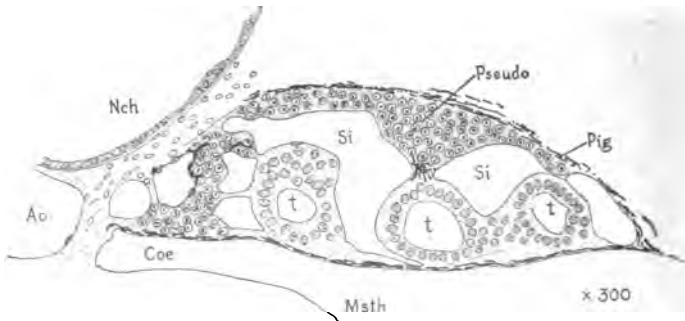


Fig. 2. *Amia calva*, embryo of 10 mm. Harvard Embryological Coll., No. 19, section 262. Pronephros in transverse section. *Nch.*, notochord; *Pseudo.*, pseudolymphoid tissue; *Pig.*, pigment cells; *Si.*, blood sinusoid; *t.*, pronephric tubule; *msth.*, mesothelium; *Coe.*, coelom; *Ao.*, aorta.

The organ may be said to consist of three parts, the pronephric tubules, the considerable masses of pseudolymphoid tissue, very similar in appearance and staining to the corresponding tissue of teleosts, and of the large blood spaces, or sinusoids; these last are

many times the diameter of a true capillary, and are bounded by an endothelium, showing very few nuclei, and fitted closely against the surfaces of the tubules and the pseudo-lymphoid masses. The pronephric tubules are almost completely surrounded by the blood channels. The blood enters the organ from the large vein at the caudad end of the organ, and passes out towards the heart through the large vein at the cephalad end. The study of this and younger stages shows that the territory of the pronephros is an interruption of the vein and that the structure figured is the result of a complicated intercrecence of the venous endothelium and the two tissues of the organ, in short, that the general scheme of development is the same as in teleosts. It should be added that Jungersen's article, '94.1, on the kidney of *Amia* contains no data on the circulation. As regards other Ganoids, I have no personal observations to offer. In the memoir by Balfour and Parker, '82.1, and in the two papers by Beard, '89.2, '94.2, there is no definite description of the circulation of the pronephros of *Lepidosteus*. Fürbringer, '78.1, p. 59, has given a few data on the head kidney of *Accipenser*, but says nothing of the blood vessels.

In regard to Teleosts, I need only repeat what I have said in my previous paper, '98.1, p. 271. The specific sections there mentioned as being in the Harvard collection demonstrate the very close resemblance of the pronephros of *Ameiurus* and *Batrachus* to that of *Amia*, and reveal a typical sinusoidal circulation.

The pronephros of Amphibia is better known than that of any other class of vertebrates. The large size and numerous free connections of the intertubular blood spaces, and the close fitting of the endothelium against the epithelium of the tubules, have been so often seen, described, and figured that there is no doubt that the circulation is sinusoidal. The pronephros of the very interesting American perennibranchiate (proteid) genus, *Necturus*, has not, so far as I am aware, been described. Fig. 3 is a section from a *Necturus* larva of 18.0 mm. The section figured passes through a nephrostome, *nst*, which I think is furnished with cilia, but as they are not clear in the preparation, which is stained only with alum cochineal, I have not drawn them in. The pronephros has a nearly circular outline and protrudes but slightly into the coelom, *Coe*. The blood sinusoids, *Si*, *Si*, occupy the entire intertubular space, and their epithelium is everywhere closely fitted to the tubular epithelium; the tubules in cross-section are nearly circular; their

epithelium is relatively thin, being thickest where the nuclei are lodged, and attenuated between the more or less widely separated nuclei, thus imparting a peculiar appearance to the sections, which is unlike what we observe in the pronephros of the gill-less urodela and anura, in which the epithelium has the nuclei closer together and the cells distinctly cuboidal in type. Opposite the nephrostome

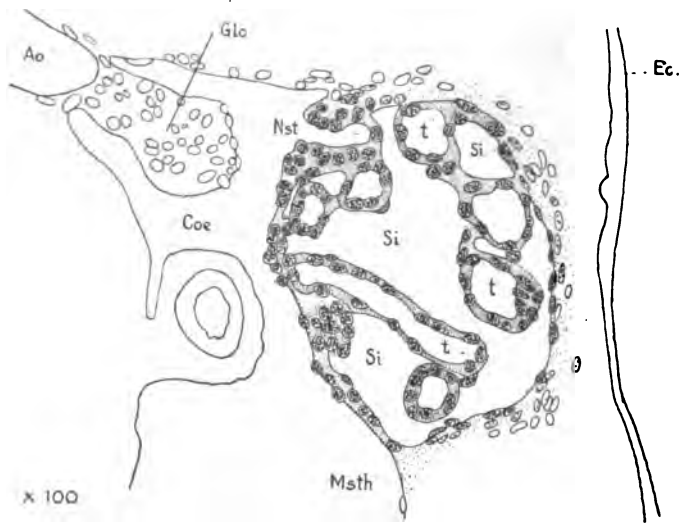


Fig. 3. *Necturus maculatus*; larva of 18.0 mm. Transverse section through the pronephros. Harvard Embryological Collection, No. 16, section 341. *Ao*, aorta; *Glo*, glomus; *Ec*, ectoderm; *t, t*, tubules; *Si*, sinusoid; *msth*, mesothelium; *Coe*, coelom; *Nst*, nephrostome.

is a large glomus, *Glo*, the base of which lies close to the aorta, *Ao*; the glomus apparently contains a network of capillaries. The great size of the cells in *Necturus* will be appreciated if figure 3, which is magnified only 100 diameters, be compared with the other figures, which are, with two exceptions, all magnified 300 diameters. In brief, the pronephros of *Necturus* shows the same type of sinusoid circulation as is well known in other Amphibia, but it has a number of distinctive histological features. Since the character of the circulation in the amphibian pronephros has been well described and figured by Max Fürbringer, '78.1, A. Goette, '75.1, H. H. Field, '91.1, and R. Semon, '91.1, it seems superfluous to dwell upon it.

In Amniota the pronephros, so far as known, is never developed into a functional organ, but seems rather to persist merely to give rise to the pronephric duct, and accordingly it never acquires a proper circulation of its own.

CONCLUSION. *The blood circulation of the pronephros is sinusoidal in marsipobranchs, ganoids, teleosts, and amphibians, and there is no exception known.*

2. **Mesonephros or Wolffian body.** I have shown in my previous paper, '98.1, that the intertubular circulation of the middle or second kidney is sinusoidal in mammals, birds and Amphibia. I wish to use the present opportunity to publish certain further considerations and observations, and a drawing to show the condition in the chick.

As regards the mesonephros of fishes we possess little information as to whether the circulation is sinusoidal or not. That it is sinusoidal is *à priori* probable from our knowledge of the conditions in Amphibia and Amniota. The very intimate relations of the cardinal veins to the renal organs have of course been long known. Thus Hyrtl (*Denkschr. Wien. Akad.*, 2, 1851, p. 34) in his paper on the kidney of teleosts writes, "Sehr oft bilden die Nierenvenen Sinuse, indem sie sich spindelförmig oder sphärisch erweitern und mehr weniger innig mit dem umgebenden Nierenparenchym verwachsen, jedoch nie so innig, dass sie nicht aus demselben ohne Verletzung ihrer Continuität herausgezogen werden könnten." He gives no information as to the vessels within the kidneys. Nor have I succeeded in finding the desired record of observations in any of the authorities whom I have been able to consult. The only new observations I can offer concern elasmobranchs. In embryos of *Acanthias* up to the length of 34.0 mm. the mesonephros is a series of segmental tubules more or less completely imbedded in mesenchyma, with the intertubular circulation scarcely developed at all. One may compare Rabl, '96.2, Taf. XVII, fig. 12, a section through the 25th mesonephric segment of a female *Pristiurus* of 30 mm., the oldest stage described by Rabl in his very valuable and careful monograph. In this and other stages near to this stage the cardinal vein lies above the base of the genital fold on the median side and quite close to the coils of the segmental organ, compare Fig. 133, p. 236, in my "Human Embryology." The blood vessels about the tubules are figured by Rabl as being *near* the epithelium only, not in contact with it. In three *Acanthias*

embryos of 28.0 mm., Nos. 232, 233 and 234 of the Harvard Collection, similar vessels are present but their endothelium is in part already fitted against the tubular epithelium; the fitting is most marked when a vessel is between two coils of the tubule. In one embryo of 34.0 mm. (H. C. No. 202) the conditions are clearer, because the vascular spaces between the tubules have increased; it is now easy to trace frequent connections between these spaces and the cardinal veins, and also to observe the diminution of the mesenchyma proper and the extension of the close adjustment of the vascular endothelium to the outer surfaces of the tubules. This adjustment is found in the dorsal region of the coils of the segmental organ, while towards the ventral side there is more mesenchyma between the coils. As illustrating this condition, I will cite section 763 of this series, No. 202, but many other sections could, equally well, be chosen. Frontal sections of another embryo of the same length (H. Coll., No. 186, sections 76, 77, *et al.*) reveal the same condition. In an embryo of 37.0 mm., the most advanced at my disposal, the intertubular vascular spaces have increased, and both their free communications with the main channel of the car-

dinal vein, and their intimate adaptation to the surfaces of the tubular epithelium, are more evident than in the embryos of 34.0 mm., so that at this stage the circulation of the mesonephros may, I think, fairly be called sinusoidal. The conditions are well shown in the sagittal sections of this embryo, Harvard Embryological Collection, No. 176, sections 87, 88, *et al.* Want of material prevents my carrying out these observations further, but I hope to be able to pur-

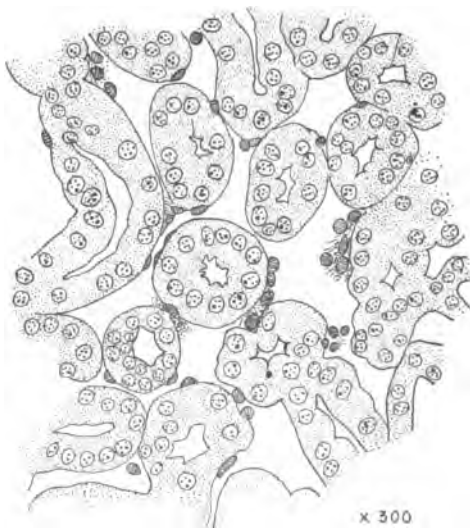


Fig. 4. *Rana virescens*, mesonephros. Harv. Histol. Coll., No. 22. Transverse section. For clearness the nuclei of the vascular endothelium are drawn dark.

sue them. Meanwhile we may say that the intertubular circulation has begun to show itself in embryos of 28.0 mm., and that it has become sinusoidal in character in close connection with the cardinal vein in embryos of 37.0 mm. It seems to me not venture-some to predict that in older embryos of *Squalus acanthias* the mesonephros will show a typical sinusoidal circulation.

Concerning the amphibian and mammalian mesonephros, I have nothing to add to what I have said in the earlier paper, '98.1. The figure of the frog's kidney is here reproduced, the magnification being changed to 300 diameters to facilitate comparison with other figures in this article. Of the conditions in the chick a few words may be said, to accompany Fig. 5. In the chick, blood sinusoids can be more beautifully demonstrated than in any other

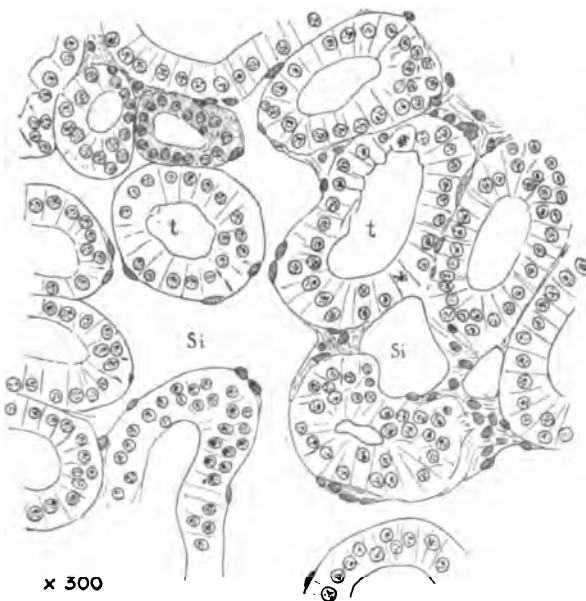


Fig. 5. Chicken embryo, supposed about 11 days, section of the mesonephros. Harvard Embryological Collection, No. 255, section 760. *Si, Si*, blood sinusoids; *t, t*, wolffian or mesonephric tubules.

animal I have studied, and this statement applies equally to the Wolffian body, the liver and the heart, see Figs. 5, 6, 7. The

nephrotome early becomes S-shaped and unites laterad with the Wolfian duct, thus becoming a Wolfian tubule, which lies in and is completely surrounded by embryonic mesenchyma, see Fig. 134, p. 238, of my "Human Embryology." In a chick of 96 hours the conditions resemble somewhat those of an *Acanthias* embryo of 28 mm., for the tubules are coiled and blood spaces are present between the coils, but there is also still mesenchymal tissue between the coils; the intertubular blood spaces communicate directly with the adjacent cardinal vein, and their endothelium is in part fitted close against the mesonephric epithelium. I have examined three embryos of this stage (Harvard Embryological Collection, Nos. 98, 99, 100). In a chick of six days (H. Coll. No. 254, slide B) the mesonephros is much developed, and although some mesenchyma is still conspicuous between the tubules, yet the blood spaces have enlarged into characteristic sinusoids, the endothelium of which adheres for most of its extent very intimately to the tubules and only here and there extends over the surface of the patches of mesenchyma. Finally in a chick of alleged ten days incubation, but apparently really older, I find the condition represented in Fig. 5. There is a layer of mesenchyma entering into the formation of the sub-mesothelial capsule of the organ, and there is some mesenchyma at the bases of the Malpighian corpuscles, but between the tubules I cannot make sure of there being mesenchyma left, save the cells of the vascular endothelium. As to how the mesenchymal cells disappear, I have not been able to satisfy myself; there is no evidence of histolysis, so that one cannot avoid the surmise that all the mesenchymal cells are utilized to form the vascular endothelium.

The method of development of the mesonephric sinusoids in the pig and the rabbit is similar to that in the chick. In these three types, as in *Acanthias*, so far as studied, there are no true capillaries in the Wolfian body at any stage. The segmental tubules are at first short and curved; as they lengthen they become coiled and as the coils increase they lie close together, so that there is space left only for a very limited amount of mesenchyma between them; after the coils have begun, and while their formation is continuing, blood spaces first appear around and between the tubules;¹ the spaces communicate freely with the adjacent cardinal vein; the blood

¹ This stage may be observed in rabbit embryos of 12½ days, while in pig embryos of 6.0 mm., the youngest of which I have sections, the interescence of vein and tubules is already well advanced.

spaces grow and at the same time the mesenchymal tissue between the tubules gradually disappears, and the endothelium fits itself against the tubules, and thus the blood spaces appear as true sinusoids. There are of course capillaries in the glomeruli.

I have examined carefully many embryos of dog-fish, chicks, rabbits and pigs, and have seen no indication of the development of true capillaries in the Wolfian body between the tubules. From their first appearance the blood channels are larger than capillaries and are in direct or almost direct communication with the vein. We must then regard these sinusoids as morphologically expansions of, or modifications of a venous blood channel. Our present knowledge of the development of the Wolfian sinusoids is very incomplete, but in my judgment it sufficiently justifies the conclusion reached. Moreover in the case of the liver the transformation of the venous channel into complicated sinusoids can be demonstrated with ease and certainty.

As regards the adult Wolfian body, it is probable that the sinusoidal type of circulation is obliterated, at least in the organ of Rosenmüller and Girdaldès. Czerny, '89.1, figures only small blood vessels not fitting against the tubules of Girdaldès. D. Popoff, '93.1, p. 300 and Fig. 11, found the tubules of the human parovarium towards the end of pregnancy, at birth, and after birth, to have lost the sinusoids. Instead of a blood space, he found around each tubule an inner thicker coat of longitudinally elongated cells and a thinner outer coat of concentrically elongated cells; both coats are apparently mesenchymal.

CONCLUSION: *The intertubular blood circulation of the embryonic mesonephros is sinusoidal in elasmobranchs, amphibians, birds and mammals. After the tubules in the embryo have become coiled, there occurs an intercrecence of the endothelium of the cardinal vein and of the tubules, which finally results in the formation of sinusoids.*

3. Liver. The intimate relations of the hepatic cylinders to the veins in the developing liver are, of course, familiarly known to all embryologists, and have become matters of text-book description; see for example Prenant, '96.1, Livre 2, p. 290; O. Hertwig, '96.1, p. 318; J. Kollmann, '98.2, p. 368; or O. Schultze, '97.3, p. 381. The description of the last is particularly concise and clear, and may therefore be quoted. "Gleichzeitig [i. e. am elften Tage] mit der Bildung des rechten Leberganges erscheinen beim Kaninchen auch

die ersten soliden Lebercylinder an dem linken Gange, d. h. kurze solide Epithelialsprossen desselben, und zugleich bilden sich von den anliegenden *Venae omphalo-mesentericae* aus zahlreiche Gefässsprossen in den grösser werdenden Leberwulst hinein. Gefässe und Epithelsprossen durchwachsen sich gegenseitig, und entsteht alsbald das typische Aussehen der jungen embryonalen Leber: ein Gerüst netzartig verbundener Epithelstränge, dessen Lücken ganz von den relativ weiten, von platten Epithelien begrenzten Gefässen ausgefüllt sind."

Although the fact that the main circulation (portal) arises as a modification of a vein, by subdivision of the venous cavity and the intercrecence of venous endothelium and hepatic cylinders, has been long and familiarly known, yet no deductions seem to have been made. On the contrary, the custom is literally universal to speak of the "capillaries" from the portal vessels through the hepatic lobule to the axial (or so-called central or intralobular) vein. But these "capillaries" are obviously in no sense homologous with the true capillaries, and, moreover, probably differ as much from true capillaries physiologically as they do morphologically. The "capillaries" *auctorum* of the hepatic lobule are true sinusoids. The establishment of this conception appears to me an important gain in anatomical science.

It is extremely easy to satisfy oneself by examining a series of embryos of a given vertebrate that the original wide sinusoids of the liver are transformed by the continual growth of the hepatic cylinders into smaller and smaller blood spaces, leaving, of course, certain wider channels as vascular trunks. *Acanthias* and the chick are particularly favorable types for the study of these changes. I will, since the essential facts are well understood, content myself with an enumeration of the principal stages in the two types mentioned, so far as covered by my personal observations. First, *Squalus acanthias*. The brief account of the development of the liver in elasmobranchs given by F. M. Balfour in his monograph (See "Works," vol. i, p. 453) is correct. The liver arises as two diverticula, which by outgrowths of their walls begin to form hepatic cylinders in stage K (*Scyllium canicula* of 10 mm.). In an *Acanthias* embryo of 11.5 mm. (Harvard Coll. No. 206, section 421) the first short hepatic cylinders are present; between them are the blood spaces derived from the vein, and the epithelium is already close against the surface of the liver cells. Precisely this relation,

which I hold to be of capital importance, appears to have been overlooked by Balfour, probably because the preservation of his specimens did not permit its recognition. In embryos of 13 mm. the hepatic cylinders have grown, and everywhere between them are typical sinusoids. In embryos of 18 mm., of which we have better preparations, the sinusoids occupy the entire room between the cylinders, and the endothelium follows everywhere the curves of the cylinders; there is a little mesenchyma at certain points under the covering mesothelium and around the entoderm of the main diverticula, but I have been unable to make sure of any mesenchyma, except the endothelium between the cylinders — compare Harvard Coll., Embryo 203, section 475 *et al.* The condition in embryos of 29 mm. I have already described in my "Human Embryology." For convenience I reproduce the figure and quote: "Every cylinder, *hp*, is an epithelial tube with a small central lumen and covered by an endothelium, which is easily recognized by its flattened darkly stained nuclei; the endothelium is the wall of the blood vessel or channel, *pl*. The hepatic cylinders by branching and uniting form a network, all the meshes of which are entirely occupied by blood vessels." So far as I am aware the true character of the hepatic circulation in elasmobranchs was first pointed out in this passage (1892). In an embryo of 34.0 mm. the reduction of sinusoids in size is marked, and they are more like separate vessels owing to the more frequent unions of the cylinders, so that we have a distinct approach towards the adult condition as described by Hermann Braus, '96.1, p. 315. The reduction is much more marked in the cephalad than in the caudad end of the liver, and in the latter indeed the sinusoids are still relatively wide — compare Harvard Coll., No. 202, slides T, U and V. The retarded development of the caudad tip of the liver as



Fig. 6. *Squalus acanthias*. Portion of a section of the liver of an embryo of 29 mm.; *hp*, hepatic cylinders; *bl*, blood sinusoids.

compared with the cardiac end can be seen in a single sagittal section, for example in an embryo of 37 mm., the oldest at my disposal, Harvard Coll., No. 176, sections 124-130.

As regards the liver of the chick, it seems to me that comparatively little has been added to our knowledge, since the publication of Remak's admirable observations, '50.1, pp. 51-53. The following summary indicates the approximate ages at which the principal stages may be observed.

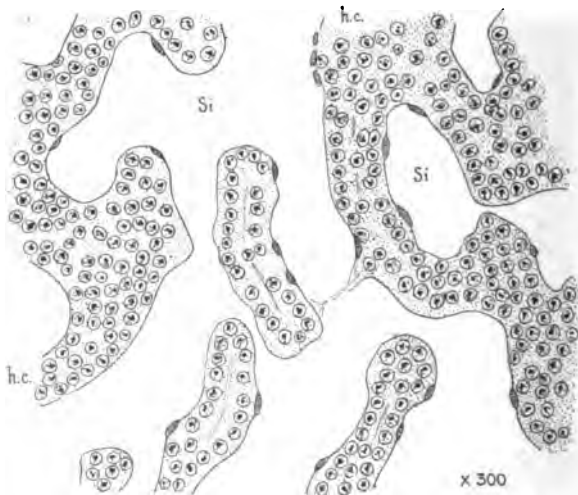


Fig. 7. Embryo chick of six days, 12.0 mm. Section of the liver; *h. c.*, hepatic cylinder; *Si*, sinusoid. Harvard Embryological Collection No. 258.

- 45-50 hours: anlage of the hepatic diverticula.
- 55-60 hours: outgrowth of the two hepatic diverticula; beginning of the solid hepatic cylinders.
- 60-90 hours: the still solid hepatic cylinders have formed anastomoses; sinusoids occupy the spaces between the cylinders and communicate freely with the subintestinal vein.
- 90-98 hours: the lumina of the hepatic cylinders begin to form, F. Froben, 92.1.

6 days: the liver has acquired considerable volume by the growth of the cylinders; the sinusoids have increased in diameter, see Fig. 7.

11 days: the liver is much larger; the sinusoids, except those forming the trunks and branches of the system of vessels, have diminished in size, owing to the increase in number and in diameter of the hepatic cylinders, see Fig. 8.

Figures 7 and 8 are drawn to the same magnification — 300 diameters — so that they may be directly compared with one another. Attention is directed to the fact that the blood spaces pass through two phases, since, *first*, they are small, and then

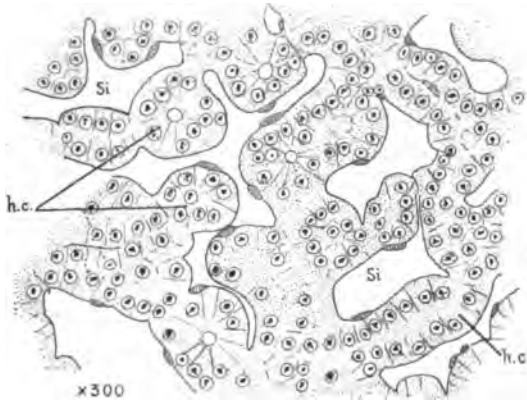


Fig. 8. Embryo chick of 11 days. Liver, part of a transverse section; *h. c.*, hepatic cylinder; *Si*, sinusoid. Harvard Embryological Collection, No. 255.

gradually enlarge, as correctly recorded by Remak, *l. c.*, and *second*, they are reduced in size by the growth of the cylinders. The first phase may be demonstrated by comparing Froben's figure, '92.1, Fig. 4, of the chick liver at 96 hours with my Fig. 7, above; for the second phase, compare Figs. 7 and 8. The sections of the various stages show that the hepatic cylinders expand, as it were, into the space occupied by the subintestinal vein; and while they expand, the endothelium of the vein forms a close covering over the surfaces of the cylinders. There is not a trace of any

capillary development, and such a development seems wholly impossible, since the organ is without mesenchyma.¹ All the blood vessels are merely subdivisions of the venous channel, and the subdivision is due to the complicated and perfect intercrescence of the wall of the vein on the one hand, and the liver epithelium on the other; these two tissues alone form the embryonic liver. The sinusoids thus produced at first increase in size, as we have seen occurs also in the pronephros and mesonephros; subsequently they are gradually reduced, the reduction going far beyond that indicated in Fig. 8, continuing, as is well known, until they appear in the adult as the small so-called "capillaries." If the term proposed in this article for the class of vessels we are studying, be adopted, the vessels of the adult hepatic lobule can be distinguished as *capilliform sinusoids*. That the transformation of the large vessels of the embryonic liver in part into the small "capillaries," *auct.*, of the adult has been long known, the following quotation from Toldt and Zuckerkandl, '76.1, p. 266, will show:—

"Nach Allem, was wir gesehen haben, sind die Capillargefässen der Leber in den frühen Embryonalstadien, ansehnlich weiter als in den späteren, und zwar sowohl absolut, als namentlich im Verhältniss zu den von ihnen umschlossenen Drüsenbestandtheilen. Noch mehr tritt dies der Leber des reifen Kindes gegenüber hervor."

Comparatively late in the development of the liver, the connective tissue dissepiments make their appearance. In this connective tissue in the adult occur true capillaries, which receive their blood supply from the hepatic artery. Although, apparently, nothing is known of their actual development, it may be assumed safely that they have genetically nothing in common with the capilliform sinusoids of the portal circulation.

In view of Alexander Goette's well-known statement, '75.1, that the first blood channels of the amphibian liver are without endothelium, further study seems necessary to ascertain how far in this class the circulation of the organ conforms to the sinusoidal type.

4. **Heart.** We have seen in the three organs studied that the anlage of the organ first develops alongside an embryonic vein, then by intercrescence of the cells of the organ with the endothelium of the vein, sinusoids arise. The cells of the organ are separated

¹ There seem to be a very few cells of possibly mesenchymatous nature in the earliest anlage, chicks of 96 hours.

from the blood only by the endothelium, and between the endothelium of two adjacent sinusoids are found only the specific cells of the organ, no connective tissue and no capillaries.

When we study the development of the heart, we find that the above brief description is as strictly and literally applicable to the formation of the trabeculae of the heart as to the formation of the trabeculae (*i. e.*, tubules) of the pronephros, mesonephros, or liver. The development of the cardiac trabeculae may be best studied in the ventricle, since they are very much restricted in the auricles. The heart, when first differentiated, consists of an inner endothelial tube, and an outer mesodermic (mesothelial) tube. From the latter arises the muscular wall of the heart; the muscular wall grows, and in the ventricle form a number of more or less separate thickenings, which project into the cavity of the heart and constitute the anlagen of the future trabeculae. From the very start, almost, the thickenings of the myocardium come into contact with the endothelium, which, as soon as the thickenings begin to protrude, forms a close investment over them. The intercrescence of the myocardium and endocardium continues, and there results a subdivision of the peripheral territory of the blood channel into many subsidiary channels. All of these facts are so well known that they constitute part of our text-book stock of information. I hold, however, in addition, that we must interpret this condition as a sinusoidal circulation, and as showing to us the first or primitive circulation of the heart itself. Later, when the coronary arteries develop, and connective tissue is differentiated in the ventricular wall, a true capillary circulation is established, just as in the liver the true capillaries appear ontogenetically late in the so-called "prolongations of Glisson's capsule." The adult heart has (? in all vertebrates) two circulations, the primary sinusoidal circulation and the accessory capillary circulation.

That these conceptions are justified is proven by a more attentive study of the embryonic heart. Fig. 9 represents a small portion of the ventricle of the heart of a human embryo of about two months, and 24 mm. long. The muscular trabeculae, *t. t.*, are completely and closely invested by the endothelium of the sinusoids, *Si.*, *Si.* The trabeculae consist of young heart-muscle cells, and so far as I have observed contain no other cells whatever. I can find no connective tissue and no suggestion of capillaries. The principle of the organization is then the same as in the pronephros, meso-

nephros and liver, in that between the sinusoids there is only one kind of cell. The fact that the cells in the trabeculae are all of one and the same kind, is well shown in Fig. 9. In another human

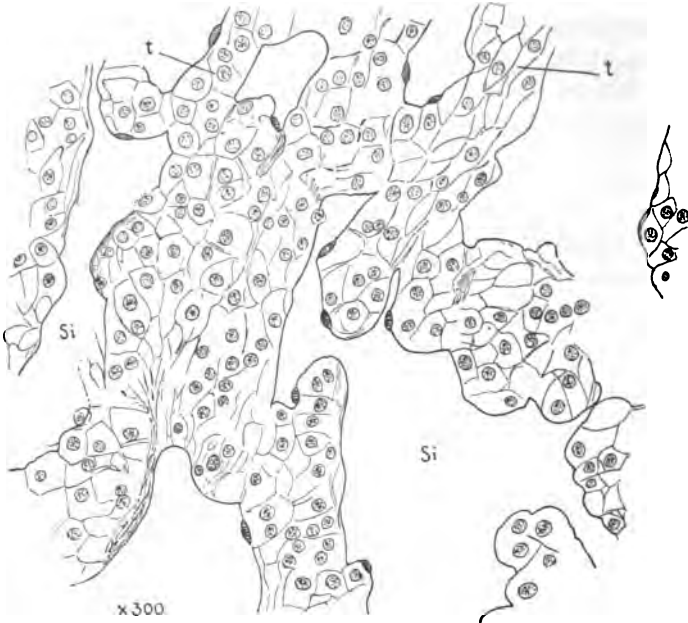


Fig. 9. Human embryo of about two months. Part of a transverse section of the ventricle of the heart. *t*, *t*., muscular trabeculae; *Si*., sinusoid. Harvard Embryological Collection, No. 38, section 185.

embryo, of almost precisely the same age, I observe the same structure of the trabeculae; this latter embryo was obtained very fresh, and the preservation histologically is extremely good, Zenker's fluid having been used; it is No. 181 of the Harvard Embryological Collection.

I have examined the ventricular trabeculae in the hearts of several young embryos of the rabbit, pig, and chick, and have found them in every case to consist only of young muscle cells with an endothelial covering. A negative assertion of this kind is of course liable to be incorrect, but it will, I believe, be found sufficiently exact to prove the importance of the heart sinusoids, by the absence

of ordinary capillaries. Under these circumstances we must assume that the nourishment of the heart is direct from its own contained blood, and that it is only later that capillaries appear. The cardiac sinusoidal circulation is important, and this appears in physiological experiments on the frog's heart, and, as Prof. W. T. Porter informs me, also in the mammalian heart after the exclusion of the coronary circulation.

What then are the conditions in the adult? Are the sinusoidal blood spaces preserved? Are the adult trabeculae covered merely by endothelium? I have sought in the text-books and in special articles in vain for definite answers to these questions. The answers must be furnished by future research. I have, however, examined the heart ventricle in two frogs, *Rana haeleina*, one cut in transverse, the other in longitudinal, section. The main central cavity in these sections is quite small; the greater part of the ventricle is occupied by a sponge-work of muscular trabeculae covered by endothelium, which bounds the blood channels, as described by Gaupp (*Anatomie des Frosches*, Abth. II, p. 256). I can also confirm Engelmann, who says (*Arch. Néerl. Sci. Exactes*, XI, p. 61) "partout, jusqu'à une très petite distance (environ 0.02 mm.) de l'ectocarde, la substance musculaire du ventricule et traversée de fentes capillaires, qui communiquent avec la cavité ventriculaire et qui sont tapissées d'un prolongement de l'endothélium de cette dernière." Examination of the sections shows that the endothelium is everywhere fitted close against the muscle cells, apparently with no connective tissue under it, and shows also that the trabeculae consist practically only of muscle cells. There are, to be sure, a few scattered pigment cells, and a few nuclei, which may possibly belong to mesenchymal cells, though I think not; but it is certain that the trabeculae consist essentially of fibrillated muscle cells. In short, the adult frog's heart has a typical sinusoidal circulation, which morphologically is identical in kind with that of the embryonic human heart, Fig. 9. The organization comprises endothelial blood spaces with the spaces between them occupied with one kind only of parenchymal cells (i. e. muscles).

5. **Supra-renal capsules.** The circulation of this organ is distinctively sinusoidal, that is to say, the vessels are wider than true capillaries, and the endothelium is closely fitted against the parenchyma formed by the supra-renal cells. By way of illustration I insert Figs. 10 and 11. Fig. 10 is from the cortex of the supra-renal

of a human embryo, the same organ the medullary portion of which is

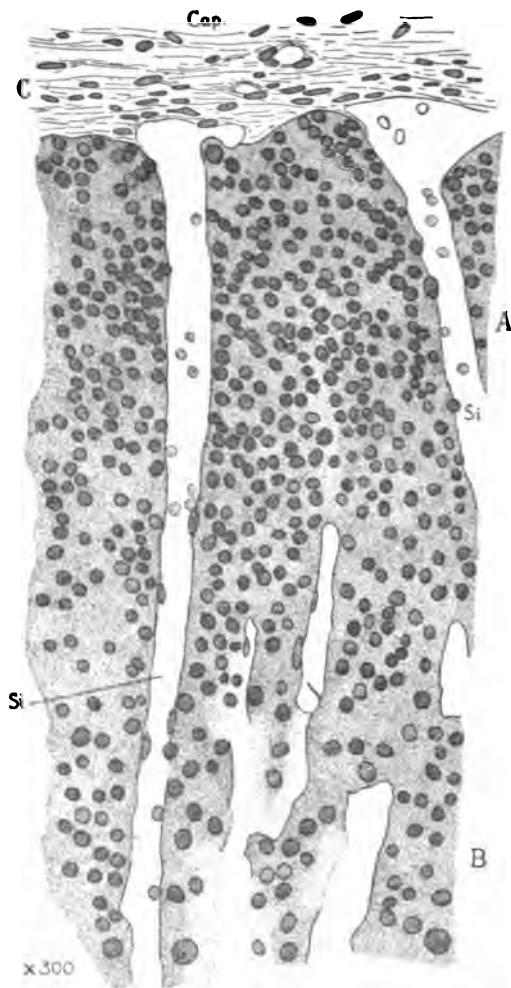


Fig. 10. Supra-renal of a human embryo of about four months, vertical section of the cortex. A, outer, B, inner zone; Cap, capsule; Si, Si, sinusoids, in which a few blood corpuscles have been represented, to indicate the width of the blood spaces.

represented in Fig. 264 of my "Human Embryology" where also, p. 488, I have briefly indicated the disposition of the blood vessels in the following words:—
 "In the cortex. . . the cords are marked off by wide capillaries, with distinct endothelial walls, between which and the supra-renal cords there appears to be no connective tissue, although in the medulla there is more or less connective tissue developed early around the vessels." M. Pfaundler, '92.1, has shown that the connective tissue capsule in certain adult mammals sends prolongations into the cortex, but these are so slightly developed that even in the cortex most of the blood spaces have very little or no connective tissue about them.

In the supra-renals of rodents the sympathetic¹ medullary portion is very promi-

¹According to Aichel (Anat. Anzeiger, xvii, 1900, p. 30), the medulla does not arise from the sympathetic.

nent in the adult. In the rat and mouse I find connective tissue to be perhaps wholly absent, certainly it is minimal in amount, if present at all, between the endothelium and the "sympathetic" cells,

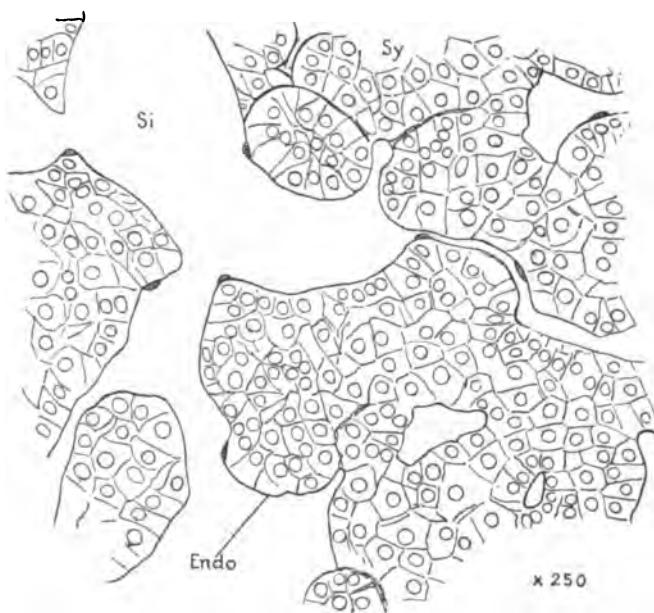


Fig. 11. Supra-renal capsule of a rat, preserved in Hermann's fluid. Section of the medulla. *Sy*, sympathetic elements; *Si*, sinusoid; *endo*, endothelium. (From Prof. Schaper's specimen, 839.)

Fig. 11. The figure is taken from a preparation for the use of which I am indebted to Prof. Schaper, and it shows the character and relations of the sinusoids with the greatest clearness.

Although the fact that the walls of the vessels within the organ, consist only of endothelium, was explicitly pointed out by Pfaundler, '92.1, it is still often overlooked both in special papers and in textbooks of histology, for example, the manuals of Stöhr, Piersol, Berdal, and others. In the American edition of Stöhr (Philadelphia, 1898) Schaper has added a figure, p. 198, in which the relations are correctly shown. The same commendation applies to the figure given of the supra-renal of the dog by Böhm and Davidoff

p. 231 (edition of 1895), a figure which Schäfer has since incorporated in his "Essentials of Histology" and in the tenth edition of Quain's "Anatomy." J. M. Flint, '99.1, has found an extensive connective tissue framework in the supra-renal, but it is very slight in its development, and does not affect the essential morphological relations, which this paper is intended to discuss. We shall recur to the question of the relation of sinusoids to connective tissue. The special character of the supra-renal circulation seems to have attracted only passing attention, and I think that the resemblance of the blood channels to the sinusoids of other organs is here pointed out for the first time.

The observations of Hans Rabl, '91.1, show, incidentally, that in the chick the type of the supra-renal circulation is the same as in mammals. I have confirmed this by observations on a chick embryo of eleven days (Harvard Coll. no. 255).

6. Parathyroid gland.

Schaper, '95.2, p. 257, has explicitly emphasized the sinusoidal character of the parathyroid circulation in certain animals, and is the only author known to me who has emphasized the physiological importance of this type of blood vessels. He writes as follows concerning the sheep,—"wo das Organ aus einem Netzwerk schmülerer oder breiterer Epithelbalken zusammengesetzt ist, dessen Maschenräume durch enorm weite Capillaren vollständig ausgefüllt werden." He further points out that the endothelium

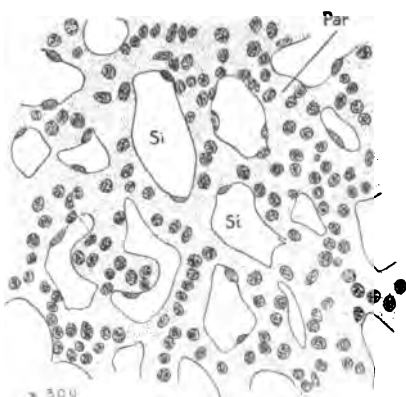


Fig. 12. From a section of parathyroid of the sheep. (From Prof. Schaper's preparation, no. 444). *Par.*, parenchyma; *Si.*, *Si.*, sinusoids.

is closely fitted against the parenchyma of the organ. By the kindness of Professor Schaper, I am able to offer Fig. 12, which is made from one of his original sections. Schaper's drawings, *l. c.*, Figs. 1, 2 and 3, represent the same features, together with accurate histological details. He terms these characteristic

vessels "lacunäre Capillaren," which name is synonymous with sinusoids. This organization is not constant even in the sheep, since the organ in many cases contains some connective tissue, which may in part form thin layers between the blood vessels and the parenchyma, and in part fill spaces between the parenchymal trabeculae. But the connective tissue is always small in amount (Schaper, *l.c.*, p. 253), so that the sinusoidal type is essentially preserved. This organ seems to me peculiarly instructive as regards the relation of sinusoids to connective tissue, a subject concerning which some brief general remarks may be found towards the close of this article.

That the human parathyroid has a similar arrangement of the blood vessels has been recorded by L. Schreiber, '98.1. Thus, for example, in speaking of the 4½ months foetus, he says, p. 719, that the blood vessels "zum Theil in den Bindegewebssepten verlaufen, zum Theil liegen ihre Endothelien ohne jegliche bindegewebige Umscheidung direkt den Epithelzellen an." His figures show this relation and also that the vessels are considerably wider than true capillaries. D. A. Welsh, '98.1, has also studied the human parathyroid, but as he had only histologically poor material, his observations provide no available knowledge concerning our special enquiry.

7. Carotid gland. In regard to the minute structure of this gland our knowledge is derived chiefly from the investigations of Paltauf, '91.1, and Schaper, '92.1. The internal circulation of the organ occurs in endothelial blood spaces, which are wider and have more frequent anastomoses than the ordinary capillaries. Between these blood spaces (and, except for a little fibrillar tissue), filling the intervals, lies the parenchyma of the organ, which consists of a cellular reticulum, in which are imbedded the relatively large parenchymal cells proper, and also nerve fibres and an occasional nerve cell. The descriptions of Schaper and his figures, especially Fig. 2, render it probable that the circulation is sinusoidal, but on this point I wish expressly to refrain from any positive assertion.

8, Coccygeal gland. According to J. H. Jakobsson, '98.1, the organ has wide blood vessels with merely endothelial walls, close about which are packed the crowded parenchymal cells. The cells form perivascular layers, and consequently cords, as it were, which are separated from one another by thick connective tissue septa. It seems, therefore, that the organ has sinusoids, and not capillaries.

Comparison of capillaries and sinusoids. Capillaries and sinusoids differ from one another in three important respects, in size and shape, in their relations to other tissues, and in their development, and it is possible that they also differ in the character of their endothelial walls. We may review briefly these four points.

1. *Size and shape.* Capillaries are of small diameter, and are usually too small to allow two blood corpuscles to move through the vessel abreast. Larger capillaries are frequently encountered, to be sure, but their calibre is never considerable. Sinusoids, on the contrary, are typically many times the diameter of a capillary; their dimensions vary between wide extremes; in the liver by a secondary change the sinusoids are reduced in size until they resemble capillaries. Capillaries tend towards a cylindrical or sub-cylindrical form; sinusoids have irregular shapes and numerous irregular connections with one another.

2. *Relations to other tissues.* A capillary is typically surrounded by and imbedded in connective tissue of mesenchymal origin. This can be clearly seen both in the embryonic and in the adult organs of all classes of vertebrates. When a capillary comes close to an epithelium, as in the villus of the intestine of a mammal, it still remains chiefly surrounded by connective tissue. In the lung of mammals the close adjustment of the capillary wall to the respiratory entoderm is a secondary acquisition, and the meshes of the capillary network retain the connective tissue. Even those cases where a capillary seems partly or wholly imbedded in an epithelium (cf. F. Maurer, '97.1, H. Joseph, '98.1, Fr. Leydig, '98.1, for interesting descriptions and discussions of intra-epithelial vessels) imply a condition which, it may be presumed, would be regarded as a secondary acquisition by every one. A sinusoid has its endothelium closely fitted against the parenchyma of the organ. So far as yet observed in embryonic stages, there is no tissue of any kind between the endothelium and the organic parenchyma. A *partial* invasion of the organ by mesenchyma between the endothelium and the parenchyma may take place, as in the supra-renal capsule, or to a greater extent in the liver, and of course if the organ enters upon a retrogressive or degenerative development, the invading connective tissue may become predominant, and completely alter the relations of the blood vessels, as in the parovarium. The relation of a sinusoid to connective tissue is certainly secondary. Nor does

it seem to me that the essential intimate relation of the sinusoid to an epithelial or epitheloid parenchyma is changed even if a minute layer of fibrillar tissue develops between them in the adult. Such a layer apparently occurs in the human liver, for instance, between the so-called "capillaries" and the liver-cells, according to observations made by Prof. F. B. Mallory with the aid of a new stain devised by him.

3. *Development.* A capillary arises from a vasoformative cell, or chain of such cells, which becomes hollowed out and connected with other vessels at both ends; it is therefore an addition by a new histogenesis to vessels previously differentiated. A sinusoid, on the contrary, is not the product of a new histogenesis; it does not arise directly from vasifactive cells, but results from the growth of the endothelial wall of a pre-existing blood vessel, and from the intercrecence of the growing endothelium with the developing parenchyma of the adjacent organ. It is possible that in some cases sinusoids arise by the expansion of capillaries — but such a process has not yet been observed. In regard to four organs we have direct observations as to the development of sinusoids, — namely, in the pronephros, the mesonephros, the liver, and the heart. For our present purpose we may regard the endocardium as an endothelial vein, and therefore say that in these four organs *the sinusoids are developed by the growth and intercrecence on the one hand of the venous endothelium, and on the other of the parenchyma* (nephric tubules, hepatic cylinders or muscles) *of the organ.*

4. *Endothelium.* If the figures in this article are examined, it will be noticed that in every case the nuclei are much farther apart than one finds them in true capillaries. I have noted this peculiarity in all the sinusoids without exception which I have studied. This observation raises the question, is there a constant difference between the endothelium of sinusoids and of capillaries? This question cannot be answered at present. The recent observations however of Kupffer, '99.1, compare also S. Mayer, '99.1, show that the supposed endothelium of the sinusoids (capillaries) of the lobule of the adult mammalian liver is not a true endothelium, but a layer of more or less widely separated mesenchymal cells. Should subsequent research prove that this peculiarity exists in other sinusoids, it would indicate an even greater morphological distinction between sinusoids and capillaries than now appears.

Physiology of sinusoids. On this subject I have only to point out the obvious fact that the physiological processes connected with the blood must occur in sinusoids under conditions very different indeed from those in capillaries. The recognition of sinusoids may be considered as equally important to the anatomist and physiologist.

Phylogenetic. In the embryo the sinusoids and true capillaries begin their development about the same time, the capillaries perhaps being the earlier. We cannot therefore assume precedence for one over the other in the evolution of vertebrates. We find in fact that when the sinusoids of the liver and pronephros appear, the capillaries of the sub-ectodermal coat are already present. This sub-ectodermal layer has not been recognized hitherto; it may be called the primitive vascular tunic or *panchoroidea* of vertebrates. On another occasion I hope to publish an account of it.

In the course of the evolution of vertebrates the sinusoids become less important. As regards the four principal organs with sinusoids, the pronephros with very wide sinusoids gives way to the mesonephros with narrower sinusoids, and the latter gives way to the kidney with true capillaries. The liver has its sinusoids rapidly transformed into capilliform vessels. In the heart with the addition of the coronary arteries the sinusoidal circulation is at least supplemented by the capillary. In all these cases the higher forms have vessels of smaller calibre substituted for larger ones directly supplying the blood needs of the tissues. This reduction in size is another example of a well-known physiological principle, of which other illustrations are offered us by the progressive reduction of size in the blood corpuscles as we ascend the vertebrate series, and by the reduction of size in the excretory tubules as we pass from pronephros to mesonephros, and then on to the kidney proper. Thus we may assume that the physiological inferiority of the sinusoidal type of circulation has led to its modification and partial obliteration in the higher vertebrates.

Harvard Embryological Laboratory,
January, 1900.

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No. 11. — *A Revision of the Systematic Names employed by Writers on the Morphology of the Acmaeidae.*

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In view of the small extent of our knowledge of the Acmaeidae, it would seem especially desirable that what is known should be rendered available by the employment of uniform terminology. This is, however, no less an unattained ideal in this small group than in other parts of the animal kingdom. It is the purpose of this brief paper to so arrange and compare the systematic names employed by various authors as to enable the reader to orientate himself with the least possible delay.

From 1758 down to the early part of this century all true limpets appear to have been included under the generic name of *Patella*. About 1830 several investigators independently separated off from the remaining members of this genus a group differentiated by the possession of a cervical gill, or ctenidium. Eschscholtz, '30,¹ called the new genus *Acmaea*; Audouin and Milne Edwards (Cuvier, '30, p. 326) named it *Tecture*; Gray, '33, p. 800, termed it *Lottia*. This name was obviously of later date than the others, and Gray himself, '47, p. 158, abandoned it in favor of that introduced by Audouin and Milne Edwards, which he seems to have Latinized into *Tectura*.² As to the use of *Acmaea* or *Tectura*, scientists are divided. The French hold to the latter, while the rest of the zoological world has agreed upon *Acmaea*. I have not found in

¹ This reference, which I have been unable to verify, I take from Watson, '86, p. 29. Dall, '71, p. 237, quotes the same work with the date of Dorpat, 1828. As he gives the name in its English form, as in a later paper, '78, p. 342, he states that the "English reprint," which was published in the spring of 1830, was dated by the author Dorpat, Jan. 7, 1828, and, finally, as Watson states that he has made unavailing search for any publication to which Dall's reference could refer, I am led to the belief that Eschscholtz's description did not issue from the press before 1830. This, however, would not affect the question of priority, since, as Watson points out, the *Ann. des sci. nat.*, t. 21, containing as it does reports of meetings held as late as Dec. 13, 1830, could not have issued from the press before 1831.

² Dall, '71, p. 239, states that he has failed to find any earlier publication of the Latin form. I have not been more fortunate. Marshall's "Nomenclator" lists *Tectura* as published in 1830 by Audouin and Milne Edwards; but this, so far as the form of the word goes, is an inaccuracy, due undoubtedly to Marshall's habit of Latinizing names.

French writers any attempt at a justification of this practice, which would seem to have arisen from the fact that *Tectura*, being proposed — at least in its French form — at about the same time as *Acmaea*, secured a position in the land of its authors which has never been successfully disputed, although its rival has undoubted right of priority. The arguments have been fully stated by Dall and Watson. Bouvier, '87, p. 22, offers one argument unmentioned in either of these statements — the great similarity between the names *Acmaea* and *Acmea*. The latter was proposed by Hartmann in 1821, but, according to Watson (op. cit.), was abandoned by him the same year. I have been unable to consult Hartmann's paper; but I am informed on excellent authority that his *Acmea* is derived from 'ακμή; *Acmaea*, on the other hand, comes from 'ακμαῖος (Rathke, '33, p. 16), and should therefore stand.

Some twenty years later this group of ctenidium-bearing limpets was itself subdivided. In 1847 Gray, '47, p. 158, apparently with some hesitation, separated from the others those which have both a ctenidium and a branchial cordon, giving to this new genus the name of *Scurria*, and restricting the name of *Tectura* (= *Lottia*) to those which lack the branchial cordon. The name of *Lottia* Gray was thus abandoned to be revived after nearly twenty years. At this time Carpenter, '65, pp. 140–141, erected a new genus for a limpet provided with both ctenidium and branchial cordon, but having the latter absent in the region of the head. As it appeared that this very animal had been figured by Sowerby, '20–'25, vol. 1, pl. 141, as the first mentioned example, and therefore inferentially as the type of *Lottia* Gray, for which Gray himself had mentioned no type species, the name given to the new genus was of course *Lottia*. So that *Lottia* Gray — or more correctly, *Lottia* Cpr. ex Gray — represents but a small part of the original *Lottia* Gray. It should be said also that some at least of the more recent authorities have reckoned *Lottia* as a subgenus of *Scurria*, so that the systematic rank of the group is a matter upon which opinions vary. And finally it may be remarked that Carpenter, '60, p. 3, had already listed this species, though without a description, under the name of *Tecturella grandis*. This name fell, owing to preoccupation.

In 1834 Broderip described a new limpet-like shell, giving no account of the animal, and entitled it *Scutella*. As this name had already been employed by Lamarck, Gray, '47, p. 168, replaced it

by *Scutellina*. Gray placed the new genus among the Patellidae; but H. and A. Adams, '58, vol. 1, p. 460, included it among the Tecturidae. This appears to have been done on the strength of their own investigation; at least they give the earliest figure which I have been able to find of the animal as distinct from the shell, and mention, although they do not figure, the gill. *Scutellina* retained its position in the Acmaeidae (= Tecturidae) either as a genus or as a subgenus (of *Acmaea*) until Dall, '89, p. 410, after a careful study of the animal, transferred the genus from the Docoglossa to the Rhipidoglossa, — a change which has been approved by Tryon and by Simroth. It is interesting to note that one of the points which decided Dall to make this transfer — the fact that the apex of the shell is posterior instead of anterior — was noted by Broderip in his original description.

Although *Scutellina* has thus been removed by most authorities from the Acmaeidae, it is still occasionally included in that group. It may, therefore, be worth while to call attention to a brief paper by Pilsbry, '91, p. 88, in which he points out that *Scutellina*, having been employed in 1841 by Agassiz for a genus of echinoderms, is preoccupied, and must therefore fall as the name of a molluscan genus. He suggests as a substitute *Phenacolepas*.

The Acmaeidae then include the following groups:—

Acmaea Eschscholtz — cervical gill, but no branchial cordon.

Scurria Gray — cervical gill and continuous branchial cordon.

Lottia Cpr. ex Gray — cervical gill and interrupted branchial cordon.

If now we examine works dealing with the morphology of the family, we find these names often incorrectly used. I enumerate all the papers known to me which treat, otherwise than incidentally, the anatomy of any one of the Acmaeidae, noting errors of nomenclature where I have found them.

1. Rathke, '33, gives a somewhat full description of the anatomy of *Acmaea*.

2. Bouvier, '87, p. 22, gives a brief account of the nervous system of *Tectura* (= *Acmaea*) *testudinalis*.

3. Bernard, '90, pp. 217–225, deals with two species of *Tectura* (= *Acmaea*) which are thus described (p. 217): “C'est d'abord la *Tectura* (*Acmaea*) *pileopsis*, qui diffère des Patelles par la présence d'une branchie bipectinée et la *Tectura* *fontainesi*, qui possède à la fois une branchie bipectinée et des lamelles branchiales circumpalléales.”

If we are to infer from this description that *T. pileopsis* differs from *Patella*, not only in the presence of a cervical gill, but also in the absence of a branchial cordon, it may possibly be identified with *Acmaea pileopsis* Q. and G., although this species is recorded by Tryon as belonging to the New Zealand, Indo-Pacific and Australian region, while Bernard (p. 217) states that his species came from Chili.

Tectura fontainesi, however, is obviously incorrectly named, and is very probably a *Scurria*. I have not been able to find trace of any member of the family bearing this specific name.

Bernard has also investigated *Lottia pellucida*, which he describes in the following terms (p. 225): "Les *Lottia* ou *Patina* sont de petits Patellidés dépourvus de branchies proprement dites, mais munis de lamelles palléales et de tentacules latéraux." This is obviously *Patina pellucida* Linn. I have found no justification for applying the name of *Lottia* to this genus.

4. Von Erlanger, '92, p. 604, describes the nephridia of an undetermined species of *Tectura* (= *Acmaea*).

5. Haller, '94, describes four Acmaeidae: *Scurria*, two species of *Lottia* Gray, and *Scutellina*. If Dall's classification of *Scutellina* be accepted, it is probable, as has been suggested by Thiele, that we have here to do with a case of incorrect determination. The description (pp. 26-27) shows clearly that the animal (supposing it to belong to a described genus of the Docoglossa) is an *Acmaea*.

The two species of *Lottia* Gray are also Acmaeas; one lacks the branchial cordon altogether; the other has irregular outgrowths which Haller (p. 27) regards as the anlagen of the cyclobranch gills. They probably correspond with *A. viridula* Lam. and *A. scutum* Orb.

6. Pelseneer, '91, p. 61, describes the eye of *Acmaea testudinalis*.

7. Thiele, '92, p. 231, describes the structure of the mantle-edge in *Collisella* (*Acmaea*) *digitalis*. *Collisella* is one of the subgenera of *Acmaea*, and according to both German and American rules the subgeneric name, when required, should be placed in parenthesis and interpolated between generic and specific appellations. The name of Thiele's species should therefore read *Acmaea* (*Collisella*) *digitalis*.

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No. 12. — *Proceedings of the Annual Meeting, May 2, 1900.*

REPORT OF THE CURATOR, ALPHEUS HYATT.

THE most notable event of the past year was the retirement of the Secretary, Mr. Samuel Henshaw, who resigned in order to accept a position in the Museum of Comparative Zoology at Cambridge. His resignation was noticed by a formal resolution, but naturally this did not allude to his long and efficient services during the time that he was an assistant in our Museum. This gentleman's name appears first in the Annual Report of 1876-77 when he took charge of our insects, and it occupies thereafter an annually increasing importance in the records of the Museum, until he became general assistant in 1883. A large part of the time from 1876 to 1883 he had worked for us without pay or with a merely nominal salary, and during those years had not only accomplished much for the insects which were under his charge, but had laid the Society under obligations for important work upon most of the other collections in the Museum. From 1883 to his election as Secretary in May, 1892, Mr. Henshaw fulfilled the duties of general assistant with exceptional ability. His active connection with the Museum consequently has lasted for about twenty-three years, and his labor has been felt in every department and always greatly to the advantage of the Society. The Curator is, therefore, very glad to be able to say that, although his work now lies almost wholly in Cambridge, he still remains connected with our Museum. He has completed the admirable cycle of his life with us by consenting to remain in charge of the insects as a voluntary assistant, thus returning to the position with which he began so many years ago.

The Society has long been in need of some separate room where the meetings of the Council could be held, and this year, principally through the efforts of the President, the northwest basement room was fitted up for this purpose and also furnished with a large blackboard and settees, so that it can be used for meetings of sections of the Society, if any are formed, or by natural history clubs or small societies that may find it convenient to meet in our building. Improvements usually have accompanying inconveniences, and this one obliged the Curator to crowd the collections heretofore stored in two rooms in the cellar into one room and to make other changes that are not yet entirely completed.

The urgent need of means with which to do work has been insisted on in these reports year after year ever since the first year of the Curator's connection with the Society, and yet in spite of this, and often repeated appeals in more public ways, the impression is still prevalent in Boston that we are not in need of money. Another impression that needs correction is still more unfavorable to our progress. This is the prevailing opinion that we are not an educational institution. In spite of all the lecturing to teachers and to students and to the public that has taken place systematically and constantly in this building for thirty years past, and in defiance of more or less frequent newspaper notices of the kind of work done here, people at large regard us as a Society whose functions, outside of a museum that is open to the public for two days in the week, are strictly private and for the benefit of members alone. These false impressions lead wealthy people who are continually giving in other directions to neglect us and even to say, if requested to give, that a Society ought to take care of itself. A few years ago I heard one of the most prominent Boston merchants and liberal givers to the cause of education say the same thing about the Institute of Technology. His complete conversion to the opposite side within a few years leads me to hope that a brighter future may be in store for us. Certainly nothing can be more without justification than that an institution like ours, devoted to the encouragement of research through its publications and to the diffusion of knowledge through its museum and lectures, can be self-supporting. It might be, if a good proportion of the citizens of Boston would be willing to tax themselves to the amount of our annual dues; but when only a very minute proportion of the citizens is willing to do this, it is practically absurd to expect us to maintain ourselves by any such means. At present the money for membership is all used up, and in fact is not sufficient to meet our annual appropriation for publications alone.

In view of this general neglect of our needs it is pleasant to notice that this year we have received a donation of ten thousand dollars that the Rev. R. C. Waterston left by his will, to be paid after the decease of Mrs. Waterston. Mr. Waterston was elected a member in January, 1860, and his death occurred Feb. 21, 1893. For about twenty years he was a helpful member of this Society, and he was selected to give one of the addresses at the celebration of our fiftieth anniversary in 1880. During the last ten years or so of his life, his increasing disabilities kept him from very active participa-

tion in the affairs of the Society, but he was always ready to assist in every way that he could, and his last generous action shows an appreciation which is very grateful, since he was thoroughly conversant with what had been done and with the future aims of our work. The Secretary's Report gives the special purpose of this donation, and it is only necessary for the Curator to add that Mr. Waterston also left his collection under such conditions that we were able to take out of it whatever was considered suitable for our uses. It was a miscellaneous collection, but we found in it a considerable number of natural history specimens that could be used in the laboratory and a few for our Museum.

The remainder of this report is given under special titles designating the different departments of the Museum in which work has been done.

MINERALOGY AND GEOLOGY.

Professor Crosby has continued the work on the general collection of minerals which was interrupted last spring by poor health. This consists chiefly in weeding out duplicate specimens, which is in itself a great improvement of the collection, besides making room for new material. He has gone over the entire collection in this way, and will use a part of this material in exchanges. A large amount of work has been done in preparation of Part 3 of the Geology of the Boston Basin, which, it is expected, will soon be ready for distribution.

TEACHING IN THE MUSEUM.

A lady of Boston, as stated in a former report, carried on this department for a number of years, and Mr. Grabau's work as the lecturer and guide to the collections and in other connected lines of public instruction was fruitful in results that justified the hope of making this undertaking a permanency. It was a really unique and successful effort to make collections effective instruments of instruction in place of the lifeless and comparatively inefficient assemblage of facts they now are in museums, and would have met with substantial aid if the good work that was done could have been made known to the proper persons. The Curator therefore, feels that appeals for the re-establishment of this department should not be dropped.

DYNAMICAL ZOOLOGY.

If it were not for the great personal interest taken in this department by the Curator, the difficulties attending its installation would have long ago led to its abandonment. Considerable work has been done in this direction by the Curator and Miss Bryant, but as usual the results appear to be small, owing to the peculiar difficulties that have to be encountered in selecting specimens that will show the relations of organisms to their surroundings.

SYNOPTIC ZOOLOGY.

The gratuitous work of Mrs. Sheldon in this department, as noted in previous Reports, still continues, and this and other aid received from her makes it possible to anticipate the final completion of this unique collection and the text of the Guide. The amount of good work put into this undertaking will then be in such a form that it can be understood and properly appreciated. The following summary gives only the bare facts of what has been done, but does not convey any idea of the amount of work involved in the study of the literature and the careful judgment and investigation needed for the selection of the drawings and specimens mentioned. The principal work of the year has been upon the Crustacea, Arachnozoa, and Myriapoda. The types of all of these have been described, eighty for Crustacea, twenty-two for Arachnozoa, and eight for myriapods. The figures selected for illustrations of structure and development are as follows: forty-five for Crustacea, thirty-eight for Arachnozoa, and five for Myriapoda. Eighteen pages of the text on Arachnozoa have been written. A large amount of work has also been done upon the Insecta, in comparing different systems of classification, by the same assistant, who has also selected and described thirty types of this class and has picked out twenty-eight figures to illustrate the fossils, the primitive forms, and early stages of development; and she has also written fifty-one pages of the text of the Guide for this class. Forty-eight figures of various groups, coelenterates, echinoderms, pelecypods, cephalopods, and pteropods, have been completed, and the text of the Guide relating to these has been revised. A beginning has also been made upon the Vertebrata, four types and ten figures of primitive forms having been selected and described, and some pages of the text written.

Miss Martin has spent considerable time in making colored drawings for this collection, under the direction of Mrs. Sheldon.

BOTANY.

Fortunately the sickness of Miss Carter as mentioned in my last Annual Report did not prevent her return to duty during the early part of 1900; and since then this lady has worked in the Museum and reports as follows. The small collection received from the Boston Museum has been catalogued, labeled, and incorporated in the Museum. The special labeling of the Lowell collection, begun some years ago, has been completed. Considerable progress has been made in the systematic arrangement of the collection of duplicates. Fifty specimens of economic fungi have been received from Seymour and Earle. Twenty-two persons have been permitted to consult and study in the herbarium.

PALEONTOLOGY.

Miss Bryant has unpacked and named and catalogued the Curator's collection of Anticosti fossils, which have been stored in the cellar for several years. These specimens had been loaned to the late Prof. James Hall, but were found, upon being opened, not to have been labeled while in Albany. The same assistant has also taken care of a small collection received from the estate of Mr. Waterston, and has spent some time in the identification of the corals recently purchased from Mr. G. K. Greene.

MOLLUSCA.

Miss Martin has been occupied mainly in the effort to bring together all of the collections in this department, which, owing to the absence of proper facilities for storage, have been hitherto necessarily kept in several different places. The Mollusca room has been furnished with suitable cases for this purpose, and the work of incorporating all the different lots of shells into one single systematic collection has made some progress. This necessarily involves a large amount of labor that will probably last for several years. The same assistant and Miss Bryant have worked over, and placed in vials and proper boxes, and numbered, the single shells, and have catalogued all of the Gasteropoda of the Roper collection. The Cyrenidae, the most valuable part of the Roper collection, containing a considerable number of types of new species and rare shells, were brought here by Mrs. Roper on her return from the West, and are

now in our collection. A full report on this collection is deferred until the whole has been properly catalogued and numbered. The shelves and specimens in Room K, containing most of the shells, and those in the gallery adjoining, have been dusted and placed in as good order as practicable, but this labor is really thrown away as long as the old cases remain in their present condition, with loosely fitting doors.

Miss Bryant has looked over our special collection of New England shells and made a list of the species needed to fill gaps in this series, and has filled a few of these gaps with shells found elsewhere in the Museum.

The Curator has continued his work upon the Achatinellidae, especially the ground shells of this family, and has practically completed the detailed descriptions in manuscript of all the species of the genera of this division throughout the whole chain of the Hawaiian Islands. In pursuance of the plan of this work, application has been made for the collections of these ground shells stored in the principal museums of this country. This part of the work has so far included only the small collections of the Yale University Museum and the Smithsonian Institution; but, as it has been going on for a short time only, and the progress has been rapid, it is thought that it will not take many months. The Curator will undoubtedly be able to enrich the collection by exchanges, and he has already found some exceedingly rare shells and some distinctly new species in the two collections so far studied.

Rev. H. W. Peck has very generously placed his collection of Achatinellidae as a loan in the Society's Building, and his Amastras and other land shells have been named and described. Mr. Oleson has withdrawn his collection of Achatinellidae, to offer them for sale elsewhere. There still remain in the neighborhood of 40,000 shells in this building, and nearly a complete set of all the species of this family; so there is sufficient material. Special observations had also been made upon all of the Oleson shells, and the only loss is in the ability to revise manuscript relating to these from time to time, an omission which will tell more decidedly upon the value of Mr. Oleson's collection than upon the memoir in which they are mentioned.

CRUSTACEA.

Professor Kingsley has completed the naming of fifty-three lots of the Amphipoda loaned to him some years since, and these have

been returned and stored in the collection. Through his kind assistance fifty-three lots of this group from the southern coast of New England have been picked out and forwarded to Prof. H. C. Bumpus as a loan to aid in his researches. The work of restoring faded labels in the alcoholic collection has been completed by Miss Martin.

FISHES AND REPTILES.

These departments have received some desirable additions from the collection of the Boston Museum, but unluckily none of these had any locality labels.

BIRDS AND MAMMALS.

In consequence of a fire that affected the upper part of the building of the Boston Museum in May of last year, the proprietors turned over to the Society their remaining specimens of birds and other vertebrates. The birds were found to have been less injured by dampness, smoke, and insects than had been expected; and about one third of them were sufficiently valuable to be retained, although none of them had special locality labels. A certain number fell to pieces and were lost, perhaps one per cent. altogether. Miss Bryant was employed for some time during the summer in getting the birds together, securing the labels and storing them in insect-proof cases. After this was done Mr. Batchelder went over the entire collection in the autumn, identified the species, and picked out all of those that were considered suitable for exhibition. A considerable number of the other vertebrates were looked over by the Curator, and a number of these were incorporated in the laboratory collections, and some few were found to be desirable additions to the Museum collections.

Mr. Batchelder has added by purchase twenty-eight birds to the New England collection. Five of these are to replace badly faded specimens, but the remainder represent species or important plumages hitherto wanting in our collection.

LABORATORY.

The room in our basement has been used as in previous years by the classes of the Boston University and the Teachers' School of

Science. A number of new diagrams have been made by Miss Martin. The Curator, assisted by Mr. Coles and Miss Martin, has rearranged the entire collection, a task requiring considerable labor, owing to the confusion into which all parts of this collection had fallen during the last ten years.

REMARKS.

An unusually large amount of time has been expended this year upon miscellaneous work not reported upon above, both by the assistants and by the Curator.

The Museum has been visited this year on days other than public days by 494 pupils representing 12 schools.

TEACHERS' SCHOOL OF SCIENCE.

Mr. Grabau has continued his work in this department without remuneration. Five short and three long excursions were made during the spring of 1899 to the seashores in the neighborhood of Boston, and to some of the freshwater ponds, for the purpose of studying and collecting living animals. One of the longer excursions was made to Cuttyhunk, one of the Elizabeth Islands, and occupied four days. The average attendance on the short trips was fifteen, and there were seventeen persons present on the Cuttyhunk trip. The longest excursion was made to Bayville on Lincoln Bay, Maine. This occupied ten days in July. Here a temporary laboratory was opened, and lectures were given. This class was divided into sections, and practical instruction in the local geology and botany was added to the marine zoological work, each section carrying on one of these subjects. A number of the inhabitants of Bayville attended this course, and the botanical section remained for ten days longer after the main body of the class had gone home. The average attendance on this excursion was fifteen. The third excursion, of ten days' duration, was made in July to Monhegan Island, Maine, under the charge of some of the advanced students of the Teachers' School of Science, who assumed Mr. Grabau's duties during his absence at the West. The average attendance on this excursion was twenty-one. No systematic work was attempted in the autumn, but two excursions were made to localities in the vicinity of Boston. This decline in the autumn is the natural prelude to the entire cessation of this work, since Mr. Grabau will probably not remain in this vicinity after this year.

Field lessons in geology were given by Prof. George H. Barton to the pupils of the Boston Normal School. The small number of these lessons was due to the prevalence of bad weather. It was stated last year that these lessons would be given up, owing to the fact that no remuneration was provided for them by the school authorities; but in spite of this Professor Barton, when appealed to again this spring, found the strength of his resolution weaker than his sympathy for the need of such instruction by pupils who were destined to be teachers. Thus in a rich city like Boston the pupils of its normal school are obliged to ask for gratuitous instruction in order to get the small amount of geological work that they feel to be necessary. The course has accordingly begun again with a class twenty-three in number. Many of these pupils, when they become teachers, enter the regular classes of the Teachers' School of Science and take the complete four years' course.

It was mentioned in the last annual report that the Trustee of the Lowell Institute had concluded to discontinue the out-of-door work of the Lowell Institute, and that Professor Barton's field courses would consequently not receive any further support from this fund. This misfortune made it necessary to appeal to other persons for aid, and luckily a patron was found who sufficiently appreciated Professor Barton's work to give the necessary amount for continuing his field lessons for one year. The solidity of Professor Barton's work, and the high esteem in which it is held by teachers, and its fine results, are appreciated by all who are acquainted with the facts, and their cessation would be a serious drawback to the progress of nature study in the schools. Our most sincere thanks and those of many teachers are due to the generous donor who has enabled us to continue this work. Professor Barton reports upon this part of our work as follows.

The regular course of these field lessons in geology, consisting of ten, was given in the spring of 1899, April 22 to June 24, inclusive. The total attendance was 149; the average attendance being 28.9; largest number present at one lesson 57, smallest number present at one lesson, which occurred on a rainy day, 8. There were ten lessons also given in the autumn of 1899, Sept. 16 to Nov. 18, inclusive. The total attendance in this course was 276, average attendance 54.8, largest number present at one time 166, smallest number present at one time 21. A great improvement on the conduct of previous courses became practicable this year, which will greatly add to their efficiency. A system of examinations was

begun with the autumn series of lessons, and was introduced as a voluntary arrangement for all those who wished to get the greatest profit from the work. These examinations were taken each week by twenty-four, who were thus obliged to be in regular attendance, and at the close of the season a final examination of three hours' length was given on the Saturday following the last lesson.

The spring course for 1900 has been begun with an attendance of 45, and will be reported upon next year. The ordinary field lessons occupy only a half day on Saturdays, a few take all day like those to Marblehead, Fitchburg, and Clinton, while those to Hoosac Tunnel take two or three days each.

LOWELL FREE COURSES.

The four years' course begun by Professor Barton last winter has been continued by a series of sixteen lessons of two hours each, or thirty-two hours of instruction, on lithology and dynamical geology, exclusive of the final examination which occupied three hours more. They began, Dec. 9, 1899, and ended April 14, 1900. The class numbered 118, and the average attendance was remarkably large, being 99.3. This course was as usual a combination of lectures with laboratory work. Trays of specimens were provided, and the teachers were required to identify the different rocks used and to be able to recognize these at sight and also to describe their texture and composition. The mineral trays contained 20 specimens each, and about 2,000 specimens were used, representing 40 varieties of the common rock-forming minerals. The rock trays contained 12 specimens each, and 14 sets were used, representing 168 varieties. The entire number of specimens used was 8,400, making together with the minerals a total of 10,400 specimens provided for class use. These specimens are now stored in our basement, in cases provided for their reception. Examinations were carried on throughout the term as heretofore, and a final examination was also held, and careful records are kept by Professor Barton of the attendance and standing of every pupil. Professor Barton expresses himself as highly pleased with the progress of the class and with the attendance; but he adds that, so far as he has been able to judge, there is not a trace of any sympathy with their work shown by the authorities at the head of our public schools. Fifty-nine members of this class were from Boston, and the balance represented thirty-four neighboring towns.

Dr. R. W. Greenleaf, who had given the lessons on botany for

six years beginning in the winter of 1891-92, was obliged to resign on account of the pressure of his professional engagements. The Curator greatly regretted this, since Dr. Greenleaf had been a most successful teacher and his courses were very attractive to the best class of teachers and productive in other results noted from time to time in previous Reports. Mr. B. H. Van Vleck continued Dr. Greenleaf's four-year course, completing the third year with sixteen lessons of two hours each, beginning Nov. 18, 1899, and ending March 24, 1900. The number of persons registered was forty, and the average attendance thirty-two. Thirty took the examination, and all passed. Two students were for adequate reasons allowed to be absent and to have an examination later by Mr. Van Vleck. The subject was the structure and physiology of algae, and numerous preparations and specimens were used, fully illustrating the more important morphological and physiological facts which it was desirable to demonstrate clearly on account of their general bearing in relation to the higher orders of plants. Mr. Van Vleck was assisted effectively by the work of Miss Cora H. Clarke; and through her kindness the class was able to do its work more advantageously and to receive pressed mounts to the number of 700, representing 25 genera and thirty species. These were gratefully received by members of the class, who highly appreciated Miss Clarke's generosity.

The Curator gave the last series of lessons in a five years' course, consisting of twenty-two lessons of two hours each, altogether forty-four hours of instruction, beginning on the 21st of October, 1899, and ending on the 15th of April, 1900. The examination has not yet been held, having been postponed until the second Saturday in May. The number of lessons exceeds that of any previous year, but it was necessary in order to carry out the plan of the whole course and finish it properly. The subjects were some of the higher orders of Insecta not finished last winter and the Vertebrata, ending with a special lesson on man. There were forty-eight tickets issued, and the average attendance was thirty-six. This course was fully illustrated as usual with specimens, and the lessons consisted partly of lectures and partly of observations made by the students themselves under the direction of the Curator, the object being instruction in the broad general facts of structural and functional relations of different animals, with only enough systematic work to enable the pupils to recognize the natural relations of the types used in the class room.

REPORT OF THE SECRETARY AND LIBRARIAN,
CHARLES F. BATCHELDER.

MEMBERSHIP.

During the past year seventeen Corporate Members have been elected. One Honorary Member, Sir William Dawson, and six Corresponding Members, Mariano Barcena, Elliott Coues, Sir William H. Flower, Hans B. Geinitz, W. T. Hoffman and Alphonse Milne-Edwards, have died.

Three Corporate Members have died: Elizabeth R. Cormier, John C. Jackson and Charles T. White, and one Patron, Edward Wyman. Two Corporate members have resigned.

The membership of the Society, corrected to May 2, 1900, consists of 9 Honorary, 130 Corresponding, and 429 Corporate Members, a total of 568. There are 16 Patrons.

The Corporate members elected during the year and the dates of their election are as follows:—

Oakes Ames, Oct. 18, 1899.
Mary A. Bowers, Oct. 18, 1899.
John G. Graham, Oct. 18, 1899.
Charles Harrington, Oct. 18, 1899.
James J. Minot, Oct. 18, 1899.
Reginald C. Robbins, Oct. 18, 1899.
R. T. Atkinson, Dec. 20, 1899.
Elizabeth E. Bickford, Dec. 20, 1899.
Henry T. Burr, Dec. 20, 1899.
George A. Hathaway, Dec. 20, 1899.
Clement W. Andrews, Feb. 21, 1900.
Laurence Curtis, Feb. 21, 1900.
George W. W. Dove, Feb. 21, 1900.
W. E. C. Rich, Feb. 21, 1900.
M. Eva Warren, Feb. 21, 1900.
Arthur W. Fairbanks, April 18, 1900.
Flora G. Roper, April 18, 1900.

MEETINGS.

Fourteen regular meetings of the Society have been held during

the year. The attendance has varied from twenty-eight to ninety-three, the average being about fifty-one.

Nineteen formal communications have been made at the meetings by fifteen persons, and eight papers have been presented by title. The lantern has been used to illustrate papers at eleven meetings.

The meetings, attendance and communications have been as follows:—

May 3, 1899. Annual meeting. Thirty-four persons present.

Reports of the Curator, Secretary, Librarian, Treasurer, and Trustees.

Mr. W. L. Tower. A quantitative study of the migration and variation of the Colorado potato-beetle.

May 17, 1899. General meeting. Thirty-one persons present.

Prof. Alpheus Hyatt. Exhibition of Gage's series of brook and lake lampreys from New York.

Mr. A. W. Grabau. Evolution of the Fusidae.

November 1, 1899. General meeting. Seventy-seven persons present.

Prof. W. M. Davis. Geographical notes of a year in Europe.

Dr. H. S. Pratt. The embryonic history of imaginal discs in the brachyceran Diptera. (By title.)

Mr. Glover M. Allen. The species of *Evotomys* of eastern North America. (By title.)

Mr. Arthur M. Edwards. Diatoms of the U. S. geological survey of the Territories. (By title.)

November 15, 1899. General meeting. Sixty-one persons present.

Mr. J. G. Jack. Forest aspects and problems in central Colorado.

December 6, 1899. General meeting. Ninety-three persons present.

Mr. William Brewster. Nesting habits of some New England birds.

Mr. H. T. Burr. The discovery of fossils in the Roxbury conglomerate.

Dr. R. P. Bigelow. Anatomy and development of *Cassiopea xamachana*. (By title.)

December 20, 1899. General meeting. Forty-five persons present.

Mr. A. W. Grabau. Notes on a geological excursion in the Rocky Mountains of Colorado.

Mr. R. H. Howe, Jr. Description of a new race of *Horizopus virens* (Linn.). (By title.)

January 3, 1900. General meeting. Fifty-six persons present.

Prof. F. G. Wright. New light on the age of the Niagara gorge.

Mr. R. T. Young. A brief report on the mammals of Prince Edward Island. (By title.)

January 17, 1900. General meeting. Thirty persons present.

Dr. R. T. Jackson. Some cases of old age characters in invertebrates.

February 7, 1900. General meeting. Thirty persons present.

Dr. C. S. Minot. Notes and illustrations of mammalian development.

Dr. G. H. Parker. The correlation between the size of litters and the number of mammary glands in the swine.

Dr. R. P. Bigelow. Notes on the development of *Cassiopea*.

Dr. C. S. Minot. On the solid or closed condition of the intestine in the chick.

Dr. C. S. Minot. On a hitherto unrecognized form of blood circulation without capillaries, in the organs of vertebrata. (By title.)

Prof. M. A. Willcox. A revision of the systematic names employed by writers on the morphology of the *Acmaeidae*. (By title.)

February 21, 1900. General meeting. Forty-five persons present.

Prof. C. H. Fernald. The gypsy moth in America.

March 7, 1900. General meeting. Fifty-eight persons present.

Dr. Frank Russell. The Moki snake dance.

March 21, 1900. General meeting. Eighty-six persons present.

Prof. W. M. Davis. Glacial erosion in the Alps and in Norway.

April 4, 1900. General meeting. Twenty-eight persons present.

Dr. G. H. Parker. The neurone theory in the light of recent investigations.

April 18, 1900. General meeting. Thirty-seven persons present.

Mr. J. H. Emerton. The common species of American spiders.

PUBLICATIONS.

During the year the following publications have been issued:—

Proceedings of the annual meeting, May 3, 1899. Proceedings, vol. 29, no. 1, 43 pp.

Variation and sexual selection in man. By Edwin Tenney Brewster. Proceedings, vol. 29, no. 2, 17 pp.

Notes on the reptiles and amphibians of Intervale, New Hampshire. By Glover M. Allen. Proceedings, vol. 29, no. 3, 13 pp.

Studies in Diptera Cyclorhapha. 1. The Pipunculidae of the United States. By Garry de N. Hough. Proceedings, vol. 29, no. 4, 10 pp.

Contributions from the Gray Herbarium of Harvard University. New Series. — No. 17. By B. L. Robinson and J. M. Greenman. Proceedings, vol. 29, no. 5, 22 pp.

The development of *Penilia schmackeri* Richard. By Mervin T. Sudler. Proceedings, vol. 29, no. 6, 23 pp., 3 pls.

List of marine mollusca of Coldspring Harbor, Long Island, with descriptions of one new genus and two new species of nudibranchs. By Francis Noyes Balch. Proceedings, vol. 29, no. 7, 30 pp., 1 pl.

The blood vessels of the heart in *Carcharias*, *Raja*, and *Amia*. By G. H. Parker and Frederica K. Davis. Proceedings, vol. 29, no. 8, 16 pp., 3 pls.

The occurrence of fossils in the Roxbury conglomerate. By Henry T. Burr and Robert E. Burke. Proceedings, vol. 29, no. 9, 6 pp., 1 pl., 2 cuts.

On a hitherto unrecognized form of blood circulation without capillaries in the organs of vertebrata. By Charles Sedgwick Minot, LL.D. Proceedings, vol. 29, no. 10, 31 pp., 12 cuts.

A revision of the systematic names employed by writers on the morphology of the Acmaeidae. By M. A. Willcox, Ph.D. Proceedings, vol. 29, no. 11, 6 pp.

In connection with the publications mention should be made of the bequest of \$10,000, received this year from the late Robert C. Waterston, the income of which is to be devoted to the Society's publications.

LIBRARY.

The additions to the library have been: —

	8vo.	4to.	Folio.	Total.
Volumes	388	77	3	468
Parts	1821	355	1	2177
Pamphlets	467	29	3	499
Maps			40	40
Total	2676	461	47	3184

The library contains 25,629 volumes, 1401 current, or otherwise incomplete, volumes, and 13,311 pamphlets.

Among the more important gifts to the library during the year have been the bequest of the late Robert C. Waterston (120 volumes), some books from Mr. James M. Barnard (29 volumes), and Field's Bibliography, received from the Trustees of the Thompson Fund.

New exchanges have been arranged with the Philosophical Society of Washington, the Kongliga Universitets-Biblioteket, Upsala, Sweden, the Royal Geographical Society of Australasia, and the Bernice Pauahi Bishop Museum, Honolulu.

One exchange has ceased. The Society now exchanges its publications with 435 institutions and periodicals.

Eight hundred and ninety-two books have been borrowed by 182 persons; 441 have been borrowed for use in the building; the library has been consulted about 350 times.

Four hundred and one volumes have been bound in 270 covers.

Twelve volumes of the Proceedings of the U. S. National Museum have been indexed. Current volumes of serials previously indexed, are indexed as received.

WALKER PRIZES.

The subjects for competition appointed for 1900 were:—

1. Stratigraphy and correlation of the sedimentary formations of any part of New England.

2. A study in palaeozoic stratigraphy and correlation.

The Committee has reported the following awards:

A prize of one hundred dollars for the essay entitled, "A study in palaeozoic stratigraphy and correlation: the Hudson River beds of the neighborhood of Albany and their taxonomic equivalents," by Rudolf Ruedemann, Ph. D.

A prize of fifty dollars for the essay entitled "Cephalopod zones in the Carboniferous of North America: a study in interregional correlation," by James Perrin Smith.

The subject for the award in May, 1901, is:—

A monograph on any problem connected with, or any group belonging to, the North American fauna or flora.

REPORT OF THE TREASURER, EDWARD T. BOUVE.

ANNUAL STATEMENT, MAY 2, 1900.

To cash received from income General Fund.....	\$6,485.31	By cash paid on account of Repairs.....	\$ 844.14
" " " Walker Fund.....	1,970.74	" " " Fuel and Light.....	274.45
" " " J. W. Randall Fund.....	250.00	" " " Insurance.....	314.00
" " " H. F. Walcott Fund.....	264.92	" " " General Expense.....	889.42
" " " Entomological Fund.....	26.05	" " " Salaries.....	8,406.00
" " " C. L. Flint Fund.....	231.01	" " " Laboratory.....	49.26
" " " Bulfinch St. Estate Fund.....	1,297.28	" " " Museum.....	966.17
" " " S. P. Pratt Fund.....	553.83	" " " Library.....	1,019.16
" " " Boston University.....	2,500.00	" " " Publications.....	1,073.03
" " " Massachusetts Inst. Technology..	200.00	" " " Walker Prizes (Advertising)	45.86
" " " Admission Fees.....	75.00	" " Trustees on account Insurance Sinking Fund.....	286.00
" " " Annual Assessments.....	1,350.00	" " Secretary for Library and Publishing account (appropriations voted by Council).....	2,335.26
" " " Museum Fees.....	168.80		
" " " Sale of Publications.....	713.45		
" " " General Expense credit.....	49.00		
" " " Donation for Library.....	100.97		
" " " Interest on deposit in Shawmu Bank.....	10.42		
Total, \$16,351.78		Total, \$16,351.78	

To cash received from Augustus Lowell, Trustee, for the Teachers' School of Science..... \$2,000.00
 To cash received from Interest on deposit in bank..... 7.32
 Balance from April 30, 1899..... 122.98

Total, \$2,130.30

By cash paid on account of Lectures and Supplies..... \$1,973.97
 Balance to new account..... 166.33

Total, \$2,130.30

To cash received from Mrs. J. M. Arms Sheldon..... \$ 600.00
 " " " Interest on deposit in bank..... 6.79
 Balance from April 30, 1899..... 1029.28

Total, \$1,636.07

By cash paid for Supplies..... \$ 10.00
 Balance to new account..... 1,626.07

Total, \$1,636.07

240 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

The reports of the Trustees and of the Auditing Committee were presented, and it was voted to accept the several reports.

The Society then proceeded to ballot for officers for 1900-1901. Messrs. J. H. Blake and J. B. Woodworth were appointed to collect and count the ballots. They reported the election of

PRESIDENT,

CHARLES SEDGWICK MINOT.

VICE-PRESIDENTS,

CHARLES P. BOWDITCH,

HENRY W. HAYNES,

WILLIAM G. FARLOW.

CURATOR,

ALPHEUS HYATT.

SECRETARY,

CHARLES F. BATCHELDER.

TREASURER,

EDWARD T. BOUVÉ.

LIBRARIAN,

CHARLES F. BATCHELDER.

COUNCILLOR FOR ONE YEAR,

Miss CLARA E. CUMMINGS.

COUNCILLORS FOR THREE YEARS,

S. L. ABBOT,

WILLIAM S. BRYANT,

WILLIAM M. DAVIS,

SAMUEL HENSHAW,

Miss CATHARINE I. IRELAND,

BENJAMIN JOY JEFFRIES,

N. T. KIDDER,

WILLIAM H. NILES.

Printed, May, 1900.

No. 13. — *The Embryonic History of Imaginal Discs in Melophagus ovinus L., together with an Account of the Earlier Stages in the Development of the Insect.*¹

By H. S. PRATT, PH. D.

With seven plates.

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INTRODUCTION.

In 1897 I published in "Psyche" a preliminary account of the origin and early development in *Melophagus ovinus* of those fundaments of the imaginal head, wings, and appendages, which may be present in the larva of holometabolic insects and are known as *imaginal discs*. The present paper is an extended account of the same matter.

Melophagus belongs to the small group of brachycerous Diptera

¹ Contributions from the Zoological Laboratory of the Museum of Comparative Zoology at Harvard College, under the direction of E. L. Mark, No. 111.

called the Pupipara, which are closely related to the muscids. Leuckart ('57) early showed the striking similarity of structure of the larval and pupal forms of the Pupipara to those of the muscids; in a former paper ('93) I have emphasized the same fact; Müggenburg ('92) has homologized the mouth parts of all the pupipars with the fly's proboscis; Brauer ('85) has shown that the Pupipara are degenerate flies and has placed them next to the Muscidae in his classification of the Diptera.

The Muscidae are classical objects for the study of imaginal discs. It was with them that Weismann inaugurated the study of these interesting bodies, and, since the appearance of his first paper in 1863, Ganin, Kowalevsky, Van Rees, and many others have published the results of investigations of them. All of these studies, however, have been on the development of the discs during the larval and pupal period of the insect's life. The embryonic history of the discs, which includes their origin and the first stages of growth, has not been studied; and no positive information exists concerning them except a short statement contained in a paper by Graber ('89), which will be spoken of later on, and the preliminary paper by myself, mentioned above.

HISTORICAL.

1. *Imaginal Discs in the Larva and Pupa.*—Swammerdam (1737-38) was the earliest investigator to observe that fundaments of the imaginal thoracic appendages in the higher insects, and even of the head in some cases, do not appear first in the pupa, but are present in the larva. He was thus the first observer of imaginal discs. He showed that in the larva of *Culex*, *Apis*, and *Pieris* the fundaments of all the legs and wings lie beneath the thoracic integument. From his time down to the present generation no additions were made to the knowledge of the subject. Numerous investigators, however, made observations similar to those of Swammerdam. Lyonnet (1760) described and figured the two pairs of imaginal discs in the dorsal portion of the meso- and metathoracic segments of the caterpillar, and added the supposition that they were the fundaments of wings. Herold ('15) described the same discs, and correctly interpreted them. Burmeister ('35) also very accurately described the imaginal wing-discs of the caterpillar, as did Louis

Agassiz ('51) somewhat later. Leuckart ('57) mentions the thoracic and cephalic imaginal discs of *Melophagus*, but without describing them or knowing their ultimate fate.

It was in the years 1863 to 1866 that Weismann ('63, '64, '66) laid the foundations of our present knowledge of imaginal discs in a series of investigations on the development of *Musca* and other Diptera, both brachycerous and nematocerous. He ('63, p. 229) found that the dipterous larva, which is apodous, and in the case of the Brachycera, acephalic, contains within its thorax six pairs of disc-like bodies. In *Simulia*, a nematocerous dipter, which is the first form he studied, they are situated near the animal's integument, although apparently not in connection with it. There are three pairs ventrally located, each pair belonging to one of the thoracic segments, and three pairs dorsally located, these being similarly distributed among the thoracic segments. All of these bodies he found in close relation to nerves or tracheae or both. He further found that they remain functionless during the life of the larva, although increasing greatly in size with the growth of the larva, and that during the metamorphosis they develop into certain organs of the imago. He called them, consequently, *imaginal discs*. He found that the three pairs of ventral discs develop into the imaginal legs, the dorsal metathoracic pair into the balancers, the dorsal mesothoracic pair into the wings, and the dorsal prothoracic pair into the anterior pupal spiracles, when these are present.

In *Corethra* (Weismann, '66), also a nematocerous dipter, he found similar conditions.

In *Musca* he ('63, '64) found the conditions very much more complicated. The six pairs of discs just mentioned he found present; but, instead of being located near the integument, they were sunk into the centre of the animal's body. An additional pair of discs was also present in the forward portion of the thorax, directly in front of and closely applied to the brain-ganglia; these he found were destined to develop into the imaginal head. Weismann also found that only a small portion of the larval body passes directly into the imaginal body, the greater part of it undergoing disintegration, so that the tissues entirely lose their identity, and afterwards the imaginal body is built up anew from the imaginal discs. To this process, the entire significance of which, however, was not understood until later, he gave the name "*histolysis*."

These early papers of Weismann have furnished the starting-

point for a large number of investigations upon the imaginal discs. He confined his studies to the *Diptera*; other insect groups were soon investigated. Landois ('71) following Herold, Agassiz, and most of the older authors, studied the imaginal wing-discs to be found beneath the dorsal thoracic integument of the caterpillar. Künckel d'Herculais ('75) showed that in the larva of *Volucella*, a muscid, the imaginal discs, although situated at a distance from the integument, are connected with it by a delicate chord, the remnant of an invagination. He also discovered two pairs of imaginal discs near the hinder end of the body of the larva, which develop into the external genital organs.

Ganin ('76) studied imaginal discs in several groups of insects, — namely, the *Hymenoptera*, *Neuroptera*, *Coleoptera*, *Lepidoptera*, and *Diptera*, — in the larvae of all of which he found wing-discs, and in those which are apodous, leg-discs as well. He added to these observations the discovery, in the larvae of brachycerous *Diptera*, of other discs than those described by Weismann. That author believed that the hypodermis of the larval abdomen went directly with modifications to form that of the imago. Ganin now showed that in, and forming a part of, the hypodermis of each of the eight abdominal segments of the muscidian larva, are four discs, two dorsal and two ventral, the tissue of which resembles that of the thoracic discs, and that they form the starting point for the growth of the imaginal hypodermis of the abdomen. Ganin likewise discovered similar discs in the epithelium of the larval mid-gut, whose fate it is to form in the same way the imaginal mid-gut; and he also discovered the important fact that each imaginal disc is made up of two kinds of embryonic tissue, ectoderm and mesoderm. Furthermore he discovered the amoeboid mesoderm cells which destroy the larval organs during histolysis.

Dewitz ('78) took up the study of imaginal discs for the purpose of reviewing the work of Ganin, Landois, and Weismann. A few years later Viallanes ('82) studied afresh the post-embryonic development of the *Muscidae*, and laid the basis of our present knowledge of the histological details of the process of histolysis in the metamorphosis of insects.

In 1882 and 1883 Metschnikoff published the first of his epoch-making studies on the destruction of tissues in certain invertebrates by leucocytes, or, as he called them, phagocytes. He discussed Ganin's observations and especially that of the destruction of the

larval organs by amoeboid mesoderm cells during histolysis in the pupal muscid. These cells, he suggests, are none other than phagocytes. Shortly afterward, Van Rees ('84) and Kowalevsky ('85) proved the correctness of this position. They showed that the process of histolysis consists of the ingestion and digestion of the functional larval tissues by phagocytes, and the building up of imaginal tissues from imaginal discs.

Kowalevsky ('87) in another paper took up the investigation of the histolysis of the internal organs of *Musca* where Ganin and Viallanes had left it, and gave the first complete account of these processes. He showed the exact method by which the muscles, digestive tract, and hypodermis of the larva are destroyed by phagocytes and the imaginal organs reconstructed from imaginal discs. And in the following year Van Rees ('88) published his extensive paper on the post-embryonic development of muscids, and completed our knowledge of this phenomenon. He showed that when the muscidian larva enters upon the pupal stage, histolysis is inaugurated by the destruction of the larval muscles, which become unfunctional directly after pupation and a natural prey to the phagocytes. Soon the thoracic hypodermis and the inner organs are attacked, and at the same time the imaginal discs begin to grow and widen out, supplying the place of the tissues which are being destroyed. The continuity of the hypodermis and of most of the internal organs is thus at no time broken, an observation which Kowalevsky ('87, p. 585) also made, correcting at the same time the statement to the contrary made by Viallanes ('82, p. 221). As these processes go on, the two large cephalic imaginal discs, which form two irregularly shaped sacs extending as diverticula from the dorsal wall of the pharynx back to the brain, begin to move forward, dragging the brain with them. Their anterior ends bend and pass ventrally, embracing the pharynx between them. At the same time their communications with the pharynx enlarge and their lumina fuse more and more completely with the pharyngeal lumen until they meet in the median line and form one single median opening, which, ever increasing in size, finally extends the entire length of the discs. The lumina of the discs and of the pharynx thus become completely merged and form together a single continuous space, and the walls of the discs and of the pharynx a single continuous vesicle. This is the head vesicle or "Kopfblase," which is destined to become the imaginal head. This vesicle remains

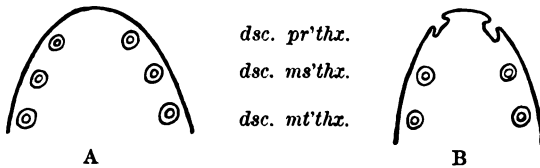
buried within the pupal thorax until near the end of the pupal period, when it evaginates and forms the completed head of the insect. This evagination has been observed by Weismann ('64, p. 259) to be the consequence of the pressure of blood, which at the right moment is forced from the abdomen into the thorax and pushes the head vesicle forward.

The metamorphosis of the thorax goes on simultaneously with the formation of the head vesicle. In proportion as the larval hypodermis disappears under the attacks of the phagocytes, as already mentioned, the edges of the imaginal discs grow and take its place, forming the imaginal hypodermis. As we have seen, there are six pairs of these discs, a dorsal and a ventral pair being present in each thoracic segment. They lie at a distance from the integument, near the centre of the larva. Each disc is, however, connected by a very fine hollow cord with that portion of the hypodermis of the segment to which it genetically belongs, and where it is destined to appear as an extremity. This cord, first discovered by Künckel d'Herculais, gradually shortens, and its lumen enlarges. The disc is thus brought nearer the surface, and as it advances it increases in size. The lumen of the cord then opens through the hypodermis, and the cord itself finally becomes so wide and short that the disc is brought through the hypodermis to the outside. The hollow cord is of course obliterated by this process, and the edges of the proximal end of the disc are brought into direct contact with the hypodermis. The disc has now assumed its position as an extremity. It is an appendage of the body-wall; it has become irregularly cylindrical in shape, and possessed of a number of constrictions and folds, which in the case of the ventral discs are equivalent to the joints of the future leg.

The metamorphosis of the abdomen is retarded; it does not begin until that of the head and thorax is well advanced. Then in each abdominal segment the two ventral and four dorsal discs (Van Rees found two additional dorsal discs in each segment) begin to grow and take the place of the disappearing larval hypodermis.

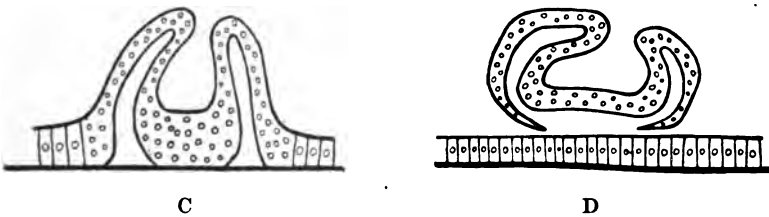
In a paper of my own ('93), which contains the results of a study of the larva of *Melophagus ovinus*, is contained a full description of the imaginal discs of this insect. *Melophagus*, being a pupipar, and closely allied to the muscids, we should expect to find the same

imaginal discs in its larva as in the muscidian larva. And we do, in-

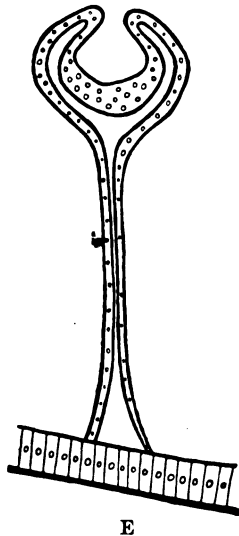


A, ventral frontal section; B, dorsal frontal section; *dsc. pr'thx.*, *dsc. ms'thx.*, and *dsc. mt'thx.*, pro-, meso-, and metathoracic imaginal discs.

deed, find similar conditions in general; but there are some interesting and instructive differences. The larva is apodous and acephalous, like the muscidian, but in many ways it is less highly special-



ized; indeed, it seems, in some respects, to occupy an intermediate position between *Corethra* and *Musca*. In the position of the thoracic discs, for instance, it closely resembles *Corethra*. These discs are found just beneath the integument in two very regular rows, and not near the centre of the larva, as in the muscidian larva. The accompanying cuts represent frontal sections through the anterior end of an old larva (Fig. A being a ventral and Fig. B a dorsal section), showing the position of the thoracic discs. In structure the meso- and metathoracic discs stand exactly halfway between the same discs in *Corethra* and in *Musca*. In *Corethra*, according to Weismann ('66, p. 78), all the thoracic discs are of *larval* origin, and each is a double fold of the hypodermis, of which it remains a part, as is shown by Figure C. In *Melophagus*, on the other hand, these discs arise in the *embryo*; they are also



double folds off the hypodermis, but become constricted off from it, as shown in Figure D. In *Musca* the discs are also of embryonic origin. They also become constricted off from the hypodermis; but, instead of remaining where they have originated, they suffer removal toward the centre of the larva, as is shown in Figure E, and the peripodal membrane, as Van Rees calls the outer wall of the disc, lengthens to form the hollow cord which connects it with its old position at the hypodermis.

In the cephalic discs the conditions are similar to those in *Musca*, but even more complicated. Instead of a single pair of head-discs there are two pairs present, one dorsal and one ventral. The dorsal pair corresponds to the muscidian head-discs in every respect; they are destined to form the dorsal and lateral portion of the imaginal head together with the compound eyes. The ventral head-discs have no counterpart in *Musca*. In the embryo they arise as a single median thickening, from which paired diverticula develop. From the bottom of each of these diverticula, which in the larva project from the ventral pharyngeal wall, there extends into its lumen a long projection. The diverticula fuse in the median line during the latter portion of the larval period, and the wall thus formed between them gradually disappears, so that in the full-grown larva the ventral discs appear as a single ventral diverticulum of the pharynx, at the bottom of which a pair of long projections extends towards the wide opening. The fate of these discs is to form the ventral portion of the head, the paired projections being the fundaments of the proboscis. The formation of the head-vesicle during the metamorphosis proceeds in a way similar to that in *Musca*. The ventral disc fuses early at its lateral edges with the dorsal pair; the communications between both ventral and dorsal discs and the pharynx become rapidly larger (in the old larva they have already become very wide), and soon the discs and the pharynx form together a single vesicle, the head-vesicle.

2. *Imaginal Discs in the Embryo*.—As already stated, the embryonic history of imaginal discs has not been studied in the higher insects. The following are the speculations of authors as to their origin.

In *Corethra*, a nematocerous dipteran, Weismann ('66) found that the imaginal discs do not make their appearance until after the last larval moult. In the *Brachycera*, on the other hand, he found the cephalic and thoracic discs present in the youngest larvae, and he

concluded that they must arise in the embryo. Concerning, however, the exact manner in which they take their origin, he was not able to make any positive statements, but was of the opinion that they first appear within the body-cavity as proliferations of the epithelial coverings of tracheae and of the neurilemma of nerves. In *Corethra*, on the other hand, he observed that the discs arise as folds of the larval hypodermis, and he calls attention to the fundamentally different method of origin of imaginal discs in these representatives of the two great divisions of the Diptera.

Landois ('71), investigating the development of wings in the larva of Lepidoptera, follows Weismann in his conclusions as to their origin in the embryo. Ganin ('76) also supports Weismann as to the embryonic origin of imaginal discs in all the different groups of insects he studied. Künckel d'Herculais ('75) was the first one who discredited Weismann's conclusions. He found each disc in the muscidian larva to be connected with the hypodermis by means of a cord, and he rightly concluded that it resulted from an invagination and that the discs are therefore of ectodermic origin. Weismann ('64, p. 139) also, it is true, saw these connecting cords, but failed to interpret them correctly. Dewitz ('78, '81) after a study of lepidopterous larva came to the same conclusion concerning the origin of the imaginal discs as Künckel d'Herculais, namely, that they are ectodermal invaginations. Pancritius ('84), also studying the Lepidoptera, reached the same conclusion. Balfour, in his textbook ('80) declared that, notwithstanding the authority of Weismann to the contrary, the cephalic and thoracic imaginal discs of *Musca* must be derivatives of the ectoderm, as they are in *Corethra*. Kowalevsky ('86), after a study of the embryo of *Musca*, declared himself unable to determine the method of origin of the imaginal discs. He arrived at the negative result, however, that they do not arise as growths from the epithelium of tracheae, but that tracheae and nerves unite with them while they are still young.

Van Rees ('88) in his studies of the muscidian larva, demonstrated the existence of a fine lumen, a continuation of the peripodal space, in the cord connecting the disc with the hypodermis, and showed that both lumen and peripodal space are lined with a fine cuticula. He asserts that this discovery is anatomical proof that the cord, the peripodal membrane, and the disc itself have all been parts of a single invagination of the embryonic ectoderm in exactly the same way as the imaginal discs in *Corethra* arise as invagina-

tions of the larval hypodermis. Graber ('77-'79), however, thought otherwise. In his valuable treatise "Die Insekten," part 2, p. 563, following the results of the first paper of Dewitz ('78), which had just been published, he introduces a diagram (Fig. 206, E) representing the thoracic discs taking their rise as deep invaginations of the hypodermis. He does not, however, commit himself to this interpretation, but says "Eine solche Annahme entbehrt aber vorläufig jeglicher Begründung, und so dürfte es doch besser sein, das Vorkommen einer endogenen Insekten-Metamorphose einfach anzuerkennen als sie mit Gewalt zu einem Vorgang umzudeuteln der mit den bisherigen Beobachtungen nicht übereinstimmt." Shortly after the publication of the above-mentioned paper of Van Rees, Graber ('89) published an extensive series of studies on the embryonic development of the Muscidae and certain other insects, in which the origin of the imaginal discs is touched upon. He adheres to the conclusions of his former work just quoted, and takes exception to those of Van Rees. Supported by certain observations on the embryonic development of *Lucilia*, he asserts that the anatomical evidence of that author does not prove the cephalic and thoracic discs to be hypodermal invaginations. Graber's observations were made on the cephalic discs and were as follows: The first traces of these discs which he found were a pair of thick plates composed each of a *single layer of epithelium* situated at the right and left of the pharynx of the larva and in connection with its lateral walls (see his Figs. 116, 117, 117*). The origin of these plates, therefore, he did not observe, but the fact that when he first noticed them they were *internal* structures, and the further fact that they were not at this early stage in the form of sacs, but of plates, led him to think that the sac-form these discs possess in their later and larval developmental stages is a secondary adaptation. In other words, he believed these discs to arise in the body-cavity of the animal as epithelial thickenings which afterward assume a sac-form. He asserts also that the possibility cannot be denied that the thoracic imaginal discs have a similar origin. In fact, this is the interpretation of the matter he himself believes.

In later years, Verson ('90) and Gonin ('94), after studying Lepidoptera, Bugnion ('91), after studying a hymenopteron, and Wahl ('99), a dipteran (*Eristalis*), have adopted the opinion of Van Rees, that imaginal discs are of ectodermal origin.

My own investigations on the embryology of *Melophagus* will

show that Graber's conclusions were in great part false. I shall show that in the Brachycera the imaginal discs of the head and thorax all arise in the embryo first as thickenings of the ectodermic body-wall, and not in the form of endogenic plates; that these thickenings soon invaginate and form simple pockets in the ectoderm. I shall show that the cephalic invaginations are formed before the involution of the embryonic head characteristic of brachycerous development, and that as a result of this involution, whereby the so-called pharynx of the larva is formed from the walls of the embryonic head, the discs come to form diverticula of the pharynx, in which condition they are found during the entire larval and the first part of the pupal period. It will also be shown that the thoracic invaginations finally become separated from the embryonic ectoderm, and form the thoracic discs as we find them in the larva; also that the external genital organs take their origin in the form of imaginal discs in the same way as do the thoracic extremities.

THE EARLIER DEVELOPMENTAL STAGES OF MELOPHAGUS.

1. *The Development of the Egg to the Completion of the Blastoderm.* — The formation of the blastoderm in the embryos of brachycerous Diptera has been observed and described by the following authors, — in *Musca vomitoria* by Weismann ('64, '82), Kowalevsky ('86), Blochmann ('87), Henking ('88), Voeltzkow ('89), and Graber ('89), and in *Lucilia* by Graber ('89). The accounts differ considerably from one another, although they are descriptions of the same process and all the authors mentioned are well-known, experienced, and competent observers. On this account, the details of blastoderm formation in *Melophagus* will be a useful contribution to the subject.

Melophagus is not, however, a favorable object for the study of the earlier stages of insect development, because of the impossibility of obtaining considerable numbers of its eggs and of determining the age of the embryos within them. The female insect produces only one egg at a time and at intervals of several weeks; each egg must be dissected from the maternal uterus, where development goes on, and the age of the embryo can be ascertained only after the egg has been properly stained, and then

only approximately by comparing it with other embryos. I should not, therefore, have selected the eggs of *Melophagus* for the investigation of this phase of insect development. My problem, as the title indicates, was quite a different one, the study of imaginal discs; but while searching for embryos containing these structures, I collected a considerable number illustrating all the different phases of the animal's development.

The egg of *Melophagus* has almost exactly the shape of that of *Musca*, as observed by Weismann ('64) and Blochmann ('87). It is an elongated cylindrical object, tapering at the poles, being blunter at the posterior than the anterior end, with a length of 1.2 mm. and an average breadth of 0.3 mm. at its widest part. As seen from the side, its ventral outline is convex, its dorsal outline slightly concave. It is covered by a two-layered chorion, the outer layer being much thicker than the inner one, and by a delicate vitelline membrane. As it lies in the maternal uterus the main body-axes of the developing embryo correspond to those of the mother's body. The micropyle forms a large funnel-shaped depression in the anterior end of the chorion (Pl. 1, Fig. 4), which sinks deeply into the yolk, and the deep dent it makes deforms the anterior end of the developing embryo until near the termination of the embryonic period. The micropyle is always found filled with a dense mass of spermatozoa.

The very young uterine egg has also a structure similar to that of the egg of *Musca*, but differs from it in one important particular. It consists of a web of granular protoplasm within which lies a mass of spherical yolk granules, but the peripheral layer of clear protoplasm is exceedingly thin (Pl. 1, Fig. 1). It has thus no "Keimhautblastem," as Weismann has called the thick peripheral layer of clear protoplasm first found by him in the muscine egg. This is rather remarkable, as the presence of the Keimhautblastem is characteristic of the higher insects, having been demonstrated in *Musca* by Weismann ('64) and others, in the Coleoptera by Heider ('89) and Wheeler ('89), in the Lepidoptera by Bobretzky ('78), in the Hymenoptera by Grassi ('84), and in the Hemiptera by Witlaczil ('84), and the absence of it is also characteristic of the lower insects, as shown by Ayers ('84), Heymons ('95), Wheeler ('89), and Korotneff ('85) in the Orthoptera, and by Brandt ('69) in the Pseudoneuroptera. The only other instance with which I am acquainted of the failure of this layer in one of the higher insects is in *Lucilia*,

a muscid, in which, according to Graber ('89), the hinder portion of the egg is provided with it, while the forward portion lacks it. Graber does not find even the thinnest peripheral protoplasmic layer in the forward half of the egg of this fly, but asserts that the yolk-balls abut immediately on the vitelline membrane, — an observation the accuracy of which seems to me on general principles extremely doubtful.

Melophagus, however, as will be seen, acquires a Keimhautblastem before the completion of the blastoderm.

The processes leading to the maturation and fertilization of the egg were not observed. The segmentation-nuclei were first observed forming an irregular group near the centre of the egg. Figure 1 (Pl. 1) represents a section of an egg in which about ten of these nuclei were counted, all of which were migrating through the yolk towards the periphery. Around each nucleus is a zone of clear protoplasm, possibly the result of the absorption of yolk granules near it. Each nucleus, moreover, as it moves toward the surface, leaves behind it a path of clear protoplasm. Only four of these nuclei are seen in the section, but portions of the paths of others are visible. It is necessary to call attention to the irregular nature of the migration of these nuclei. In *Musca* the earlier segmentation-nuclei are described by Blochmann and Voeltzkow ('89) as advancing in very regular order towards the surface of the egg from the centre and arranging themselves in positions approximately parallel to the surface as they advance. Kowalevsky ('86) observed that the segmentation-nuclei in *Musca* arrive at the surface of the egg first in the hinder portion, then in the forward, and lastly in the central portion. Voeltzkow ('89) observed in the same animal that at all portions of the egg they arrive at the same time. In *Melophagus*, as will be seen in Figure 1, most of the nuclei are near the centre of the egg, but are advancing quite irregularly towards the surface, as is indicated by their plasma-paths. The peripheral plasma-layer in this egg is very thin, being but 5 μ thick.

Figure 2 shows a section of an egg in which blastoderm formation has advanced much farther. The paths of the advancing nuclei form here a network among the yolk granules. Some of the nuclei are seen to be in the process of division; but the great majority of them are spherical bodies with distinct nuclear membranes and few chromatin granules. Many have reached the periphery of the egg.

and it will be readily seen that there is not the slightest order in their arrangement, nor is there any regularity in the way they advance. Figure 3 represents a portion of the same blastoderm on a larger scale. The peripheral protoplasmic layer has the same thickness as in the last egg mentioned, except at those places where nuclei have entered it. Here its thickness is increased by the diameter of the nucleus, which on the average is $12.5\ \mu$.

Figure 4 represents a section of an egg in which the formation of the blastoderm is still farther advanced. The nuclei begin to crowd one another at the surface of the egg, and, not finding room for themselves in the narrow, peripheral, protoplasmic layer, they begin to project outward, and thus form protuberances on the outer surface of the egg, giving a section the wavy outline shown in the figure. This protoplasmic layer has increased somewhat in thickness (probably as a result of the consumption of yolk granules by the rapidly dividing nuclei), and is now $7.5\ \mu$ thick between the nuclei. As will be seen in Figure 5, which shows a much enlarged view of a portion of this blastoderm, the nuclei have nearly the same diameter as those shown in Figures 2 and 3, and are proliferating much more rapidly. The protoplasmic paths are not so numerous as in the egg last described, and will become less frequent from now on, showing that the yolk granules move together again, thus obliterating the paths. The gradual thickening of the peripheral protoplasmic layer also probably goes on at the expense of these paths.

These processes all continue. The segmentation nuclei at the surface increase very rapidly in number, and begin to decrease in size as they become more and more numerous, and the protuberances which they occupy begin to crowd one another (Pl. 1, Fig. 6). These do not, however, show a tendency to merge with one another. Each protuberance becomes rather more clearly defined and distinct, and its sides, from forming acute angles with the plane of the former surface of the egg, as shown in Figure 4, finally come to form right angles with it (Fig. 6). The surface of the egg then presents a curious appearance, being like the pavement of a street the blocks of which are separated by deep narrow spaces. The average diameter of the nuclei in the egg represented in Figure 6 is $5\ \mu$. The peripheral protoplasmic layer has also increased in thickness, and now measures $15\ \mu$ at points between the nuclei. It now constitutes a blastema, such as is present in *Musca* before segmentation begins.

The nuclear paths in this egg have entirely disappeared. Their disappearance undoubtedly accounts largely for the increase in the thickness of the blastema.

The steps in the formation of the blastoderm between this stage and the completed blastoderm I have not observed, but I believe the concluding process to be as follows: The nuclei and their protuberances still further increase in number, and the former decrease in size; the latter are brought into immediate contact with one another and their walls fuse and become the lateral boundaries of the future blastoderm cells; these boundaries are carried still farther toward the inner surface of the blastema, and the cells are finally completed by the formation of a wall bounding their inner ends. In the completed blastoderm (Pl. 1, Fig. 7) there is still a narrow blastema present, and the diameter of the nuclei has fallen to $2.5\ \mu$. No inner or secondary blastema, such as is described in *Musca* by Graber ('89) and other authors, is present. I did not observe the formation of the pole-cells.

2. *The Formation of the Mesoderm and of the Proctodeum and Stomodeum.* — At the time of its completion, the blastoderm is composed of narrow cells of equal height throughout. In the centre of the egg are numbers of so-called yolk-nuclei. Inasmuch as these yolk-nuclei are homologous to the primitive endoderm in the gastrulation of the majority of animals, as has been determined by Heymons ('95, '97) and other authors, the stage of development in the ontogeny of *Melophagus* in which the blastoderm is completed, as represented by Figure 7, would be the gastrula-stage. The next step in the development is the formation of the germinal plate and the median mesodermal band. The cells on the concave (dorsal) side of the egg diminish somewhat in height (Pl. 2, Fig. 8); those on the convex (ventral) side rapidly proliferate along the median line; a slight depression appears in the blastoderm along the mid-ventral line, on the inner surface of which a ridge of cells, the primitive mesoderm (*crs.ms'drm.*), is raised, projecting into the yolk. The ectodermic cells of this ventral region become elongated, and with the mesodermic cells constitute the germinal plate. The plate does not, however, confine itself to this portion of the egg, but, as is common in the *Diptera*, quickly extends itself to portions of the dorsal side, the thickened ectodermic portion encircling both poles of the egg and occupying about a third of the dorsal surface at each end (Pl. 2, Fig. 9). The primitive mesodermal plate also extends

beneath these dorsal ectodermic thickenings, but is not formed at the same time at the two poles of the egg. At the anterior end it extends dorsally more rapidly than at the posterior portions (Fig. 9). I found no trace of the lateral gastrular invaginations which Graber ('89) describes in *Calliphora* as accompanying the median invagination, and which, as Korschelt and Heider ('92, p. 812) have remarked, undoubtedly mark the edges of the germinal plate.

The germinal plate, as in other Diptera, is superficial in position and unprotected by embryonic envelopes, the amnion being represented by only the merest rudiments at the anterior and posterior extremities of the germinal plate (Pl. 2, Fig. 9, *am.*), on the dorsal surface of the egg. These rudiments mark the limits of the head-fold and the tail-fold, the former being the dorsal portion of the germinal plate at the anterior end of the egg (*pli. ce.*), and the latter the dorsal portion of the germinal plate at the posterior end of the egg (*pli. ca.*). Even these rudiments of an amnion disappear in the stages immediately following.

Figure 9 represents a sagittal section of an embryo somewhat older than that shown in Figure 8. The anterior end of the egg is marked by the presence of the micropyle (*mr'py.*). The head-fold (*pli. ce.*) extends as far as the anterior amniotic rudiment and contains mesoderm, whereas the tail-fold (*pli. ca.*), which extends to the posterior amniotic rudiment, consists as yet exclusively of a thickened ectodermic plate.

The proctodeum and stomodeum both make their appearance as ectodermal depressions on the dorsal portion of the germinal plate. In common with *Musca*, as observed by Graber ('89) and Voeltzkow ('89), the proctodeum appears first. Figure 10 (Pl. 2) represents a sagittal section of an embryo somewhat older than the one previously mentioned; in it the proctodeum has the form of a deep invagination in the tail-fold, while the stomodeum has not yet appeared. The point in the head-fold where the stomodeal invagination will appear is, however, plainly shown in the thickening near the end of the fold (*cras. stmd.*). It will also be noticed in this embryo that the primitive mesoderm has extended beneath the tail-fold, that the posterior amniotic rudiment has disappeared, and that the germinal plate has begun to show traces of segmentation. Tracheal invaginations have not yet made their appearance.

Figure 12 (Pl. 2) shows a stage still older than the one just discussed, in which both proctodeum and stomodeum are present.

The proctodeal invagination (*prd.*) has become much deeper, and at its inner end the beginnings of the Malpighian tubules have made their appearance (*tb. mpg.*). The stomodeal invagination (*stmd.*) forms a deep depression in the head-fold a third of a millimeter from the anterior end of the egg. A surface view of the dorsal aspect of an egg in this stage of development is represented in Figure 11 (Pl. 2), and one of the lateral aspect, in Figure 13. In both these figures the head-fold (*pli. ce.*) is seen to be sharply marked off from the remainder of the dorsal integument by the presence of the rudiment of the amnion (*am*). The tail-fold is not marked off with the same distinctness for two reasons: the posterior rudiment of the amnion, which appeared in Figure 9, has now disappeared; moreover the fold itself does not occupy as much of the dorsal surface of the egg as it did in the previous stages, as is shown by the position of the proctodeum nearer the posterior pole of the egg.

The primitive mesoderm also shows a marked advance in development in eggs of this age. The band or ridge of mesoderm which took its origin in the mid-ventral line of the germinal plate has separated into two lateral bands which, as in other insects, occupy positions to the right and left of the mid-ventral line. Figure 13 shows these bands (*tae. ms'drm*) as they appear in a lateral view of the embryo; Figure 15 (*tae. ms'drm*), in a cross-section. It will be seen that the mesodermal cells have entirely abandoned the mid-ventral portion of the egg, a space being left between the yolk and the ectoderm which represents the fundament of the coelom (*coel.*). The formation of these lateral mesodermal bands, as just described, takes place, however, only in the middle portions of the egg. At the two ends of the egg and in the head- and tail-folds the mesoderm does not entirely abandon the median portions of the egg, although it expands into the lateral portions of it. The mesoderm of the ventral side is continuous at the ends of the egg with that of the head- and tail-folds. Thus at each end of the egg there is a continuous layer of mesoderm lining the entire inner surface of the ectoderm (Fig. 12), instead of two lateral bands, such as are found in the middle portions of the egg.

In embryos of this stage segmentation is distinctly indicated in the ventral portions of the germinal plate, ten or eleven segments being represented (Pl. 2, Figs. 12, 13). The tracheal invaginations also appear (Fig. 13), there being eleven pairs of them, of

which the first two pairs are near the anterior pole of the egg. The endoderm has now made its appearance and is in process of surrounding the yolk. As has been demonstrated by Voeltzkow ('89) and Graber ('89) in *Musca*, by Heymons ('95) in *Forficula* and various orthopterous insects, and by Lécaillon ('98) in *Coleoptera*, so in *Melophagus* the endoderm is a derivative of the inner ends of the stomodeal and proctodeal invaginations. The first indication of it is a proliferation of cells at the inner end of the proctodeum. This extends itself forward, in the form of a single layer of epithelium, along the dorsal surface of the yolk (the proctodeum having a dorsal position) to the head-fold (Fig. 12), and also around the sides of the yolk toward the ventral side of the egg (Fig. 15, *en'drm.*). As is to be seen in Figure 10 (*prd.*), the proctodeal invagination, when it first appears, is bounded on its inner end by the mesodermic layer of the tail-fold. The boundary between mesoderm and ectoderm in this region is always perfectly easy to determine, because of the very different character of the cells of the two germ-layers. As the proctodeal invagination increases in depth and the fundaments of the Malpighian tubules begin to appear, the mesodermic layer gradually becomes thinner, until it entirely disappears. The cells of the anterior (deep) portion of the ectodermic invagination then proliferate rapidly and give rise to endoderm (Fig. 12, *en'drm.*).

The proctodeum, since it appears earlier than the stomodeum, apparently gives rise to the greater part of the endoderm, — an observation which was also made by Graber ('89) on *Musca*. In the stage represented by Figure 12 the endodermal epithelium has extended forward from the proctoderm to the head-fold, and lies beneath the stomodeum, but without having fused with it. I do not believe, however, that the stomodeum fails to cooperate in the production of the endoderm. As shown in the figure last mentioned, the stomodeum has just pushed its way through the mesodermic layer, which at first bounds its inner surface; in the stages succeeding this, as will be shown very soon, this inner surface fuses with the endoderm and apparently aids in its formation.

No trace of coelomic sacs appears in the mesoderm at any time.

THE ORIGIN OF THE IMAGINAL DISCS.

1. *The Cephalic Discs*.—*a. The Early Development of these Discs.*—Soon after the stage of development represented by Figures 11–13 (Pl. 2), but before the lateral mesodermal bands have extended to the dorsal side of the embryo and joined each other in the mid-dorsal line, and before the endoderm has extended around from the dorsal to the ventral side of the embryo (Fig. 15, *en'drm*), those imaginal discs which are destined to form the imaginal head have made their appearance. Three crescentic thickenings of the ectoderm appear in the vicinity of and partly encircling the stomodeum, a median one in front of the stomodeum, and two paired ones behind it (Pl. 3, Fig. 17). The median thickening (*dsc. ce. m.*) is destined to form the ventral cephalic disc, which during the metamorphosis develops into the ventral portions of the imaginal head together with the mouth-parts; the paired thickenings (*dsc. ce.*) form the dorsal cephalic discs, which are homologous with the cephalic discs of the Muscidae, as described by Weismann, Van Rees, and others. These develop during the metamorphosis into the dorsal and lateral portions of the imaginal head. The median disc has no homologue in the Muscidae.

There is no period in the development of the embryo of *Melophagus* when a distinct head is present, although it seems probable that the head-fold, since it forms the forward end of the germinal band, represents the head. It never shows, however, the slightest trace of segmentation. In *Musca*, according to Weismann ('64) the head is, at a certain stage of the embryo's development, quite as distinctly segmented as the trunk. As will be seen in Weismann's Figure 71, the embryo is divided into fourteen or fifteen segments, of which eleven belong to the body, and the remainder to the head. The anterior portion of the germinal band does not, as in *Melophagus*, extend onto the dorsal side of the egg, the stomodeum being sub-terminal. As the development of the embryonic fly advances, the cephalic portion gradually becomes reduced in size relatively, and its segmentation becomes less distinct. When the young larva is finally born its head has been reduced to a mere rudiment at the forward end of the body, without a trace of segmentation, and is smaller than any of the body segments. Consequently, of the twelve segments composing the fly larva the first alone represents the head.

In the development of the embryonic *Melophagus* the head-fold has a history similar to that of these cephalic segments of *Musca*. As the embryo advances in its development the head-fold diminishes in size, and the stomodeum, which first appeared at some distance from the anterior end of the egg on the head-fold, migrates forward towards its definitive position at the anterior end, probably as the result of a longitudinal concentration or shortening of the germ-band. The history of the tail-fold is the same. It also becomes reduced in size as the proctodeum migrates towards the posterior end of the embryo. This migration is much more rapid than that of the head-fold. Thus, when the young *Melophagus* larva is finally born, it resembles externally in a marked degree the new-born fly larva. It consists of twelve segments, of which eleven belong to the body, and one, which represents the rudiment of the head-fold, to the head; the head- and tail-folds have disappeared, the germ-band having entirely retreated from the dorsal side of the embryo.

The further development of the cephalic discs goes on hand in hand with this migration of the stomodeum towards the anterior pole of the egg. The paired discs develop much more rapidly than the median one. The latter remains a mere thickening of the ectoderm, without showing signs of invagination, during the entire migration of the stomodeum, so that when this organ has reached its final position at the anterior end of the egg the median disc has simply changed its position. It is now an ectodermal thickening on the *ventral* side of the embryo just beneath the mouth opening (Pl. 3, Fig. 22, and Pl. 4, Fig. 29, *dsc. ce. m.*).

The paired discs, on the contrary, early in the course of their movement forward begin to invaginate. The convex margin of each of the crescentic thickenings becomes much thicker than the concave, and along this outer (convex) margin a groove-like invagination is formed (Pl. 2, Fig. 14, *dsc. ce.*). At the stage of development represented by Figure 14, the right and left halves of the germinal band in the region of the body have not proceeded more than half way towards the dorsal side of the egg, as will be seen in Figure 15 (*tae. ms'drm.*), which represents a cross-section through the middle of the same embryo as the one shown in Figure 14. The endoderm has not yet extended to the ventral side of the yolk (Figs. 14, 15, *en'drm.*), the tracheal invaginations form deep sacs (Figs. 14, 16, *i'vag. tr.*), and the nervous system has not yet made its appearance.

An embryo which has advanced somewhat beyond the stage just discussed is illustrated in Figures 18-21 (Pl. 3), which represent sections through a single animal. The stomodeum (Fig. 18, *stmd.*) has become a deep invagination, which is situated on the dorsal side of the embryo, 0.16 mm. from its anterior end. It has thus moved 0.17 mm. nearer the anterior end than it was at the stage represented in Figure 12. The inner end of the invagination has now fused with the endoderm. The forward ends of the paired cephalic discs appear in this section (Fig. 18, *dsc. ce.*). At a distance of 0.08 mm. back of this section is the section represented by Figure 19, which shows these discs where the invaginations are deepest. The invaginations are here long, curved, deep slits, one on each side of the stomodeum, which have a diagonal position in the head-fold, the median end of each being directed posteriorly. It will also be observed that in this embryo the endoderm has completely enclosed the yolk. At the anterior end of the embryo it has fused with the stomodeum (Fig. 18), while at the posterior end it is seen to be continuous with the proctodeum (Fig. 21, *en'drm.*). The nervous system has made its appearance in the form of a pair of longitudinal cords of cells on the ventral wall of the body, one on each side of a mid-ventral ectodermal ridge (Pl. 3, Figs. 18-20, *n. v.*). In the head-fold a longitudinal nerve-cord makes its appearance immediately beneath each cephalic invagination and on the median side of the slit-like invagination (Figs. 18, 19, *gn. cb.*); these connect with the ventral nerve-cord at the forward end of the embryo. These nervous fundamentals in the head-fold are undoubtedly the beginnings of the cerebral ganglia. This early establishment of a relation between the brain of the animal and the paired cephalic discs is important, since the relation becomes more intimate as development advances. In the larva and pupa the cephalic discs are so firmly joined to the cerebral ganglia that Weismann ('64), who first discovered the corresponding discs in *Musca*, gave them the name "Hirnanhänge."

A pair of large spherical bodies, apparently of nervous tissue, appears in the head-fold at this stage of development (Pl. 3, Fig. 18, *gn. ala.*) at the right and left of the stomodeum, and near the forward ends of the cephalic invaginations. The origin of these very noticeable bodies I did not observe; but they arose between the stages represented by Figures 14 and 18, and probably from the ectoderm. They are at this stage quite unconnected with any other

organs. It is very difficult to identify them satisfactorily, but apparently they belong to the pharyngeal (sympathetic) ganglionic system, and I have called them *ganglia allata* (see Heymons, '95, p. 49), inasmuch as they do not arise from the dorsal stomodeal wall, but probably from the outer ectoderm, whence they migrate dorsally to the position they finally occupy. In other insects in which these or at least similar ganglia appear, they originate as thickenings or invaginations of the ventral body-wall in the neighborhood of the maxillae, and migrate dorsally either to fuse with each other in the mid-dorsal line just above the stomodeum (Forficula) or to remain separate (*Gryllus*). In *Melophagus*, since the head-fold and the stomodeum occupy the dorsal portion of the germinal band, these ganglia probably do not have a ventral, but rather a lateral, origin (Pl. 3, Fig. 18, *gn. ala.*). But, as will be seen in subsequent stages, they migrate to a position immediately beneath the dorsal body-wall, fuse together, and enter into relations with important pharyngeal organs.

No neuroblasts appear in any part of the nervous system at this early stage of development, the cells being spherical bodies of nearly equal size. The germinal band has not, in the stage just discussed, grown over the dorsal side of the animal (except, of course, on the head- and tail-folds) to complete the formation of the back.

In the next stage the stomodeum (Pl. 3, Fig. 22, *stmd.*) has reached the forward pole of the body. The cephalic discs have also changed their positions and migrated farther forward. The median disc is now situated immediately ventrad of the mouth opening (*dsc. ce. m.*); the paired discs have moved still farther forward, and are now 0.15 mm. from the anterior end of the animal; but their essential character has not changed. Figure 23 (Pl. 4) represents a parasagittal section of the same embryo of which Figure 22 represents a slightly oblique sagittal section. It, together with Figure 26, — which represents a cross-section of an embryo of the same age, — shows the relation of the paired discs to the surrounding organs. These discs (*dsc. ce.*) are seen to be no longer dorsal to the embryonic intestine, as in the previous stages, but to have moved to a position in front of it.

The nervous system has developed considerably. The paired nerve-cords (*n. v.*) have fused with the mid-ventral ectodermic ridge, and neuroblasts appear throughout their entire extent. The

paired cerebral ganglionic fundaments (*gn. cb.*) beneath the paired discs have increased in size. Figure 23 shows their connection with the ventral cords. The ganglia allata (*gn. ala.*) have moved to the dorsal side of the embryo, where their anterior ends have fused with each other, and occupy a median position (Pl. 3, Fig. 22, and Pl. 4, Fig. 26, *gn. ala.*), while their paired posterior portions lie back of the paired discs (Fig. 23, *gn. ala.*). A still better idea of the position of these bodies is given in Figures 43 and 44 (Pl. 7), although these represent sections of a much older embryo, Figure 44 (*gn. ala.*) showing the posterior portions of the ganglia, and Figure 43 (*gn. ala.*) their juncture. Their anterior fused portion, even in the earlier stage (Pl. 3, Fig. 22, *gn. ala.*), has much elongated, and extends forward to a mass of mesodermic tissue, dorsal to the forward portion of the stomodeum, which is fast developing into a group of muscle-fibres (*lng.*), whose later history will be found to be interesting. In the dorsal wall of the stomodeum is to be seen a slight evagination (*gn. f.*, Pl. 3, Fig. 22; Pl. 4, Fig. 26), which I take to be the fundament of the ganglion frontale. It is a very transitory structure, soon disappearing without leaving a trace in the later history of the animal.

Segmentation has become much more strongly marked in the forward portion of the embryo, but has almost disappeared from the hinder portion of it. In Figure 22, which represents a somewhat oblique sagittal section, we see three deep grooves in the ventral ectoderm, which mark the boundaries between head, prothorax, mesothorax, and metathorax, respectively. Two following shallow grooves mark the boundaries of the metathorax, the first, and the second abdominal segments respectively.

The arrival of the stomodeum at the anterior end has transformed that part of the body of the embryo. The mouth is a transverse, slit-like opening (Pl. 4, Figs. 25 and 27, *stmd.*). Its ventral lip is the median cephalic disc, which, however, is still only a thickened portion of the ectoderm. Its dorsal lip is a conical structure, and projects freely forward above it (Pl. 3, Fig. 22; Pl. 4, Fig. 27, *lng.*). This structure is of great importance in the larval life of the insect, for it acts as a sucking tongue by means of which the animal ingests its milk-like food. (For a description of it in the larva, see Pratt, '93.) When it first appears, this organ, as will be seen in Figure 22, forms the dorsal wall of the anterior end of the stomodeum, and its anterior tip projects beyond the

remainder of the body. These relations are also to be seen in figure 27 and in the cross-sections shown in Figures 24 and 25, Figure 24 being a section through the extreme anterior end of the animal, in which the ectoderm is the only tissue cut, and Figure 25 being a section just back of it. The sucking tongue is composed of two distinct tissues, an outer epithelium and an inner muscular core (Figs. 22, 25, *lng.*). At the stage represented by these figures the muscle-fibres are just beginning to differentiate. The hinder surface of this muscle mass is in direct contact with the fused median portions of the ganglia allata (Fig. 22). Figures 27 and 28 represent surface views of an embryo in this stage of development.

It will be noticed in Figure 22 that a communication between the intestine and the proctodeum is established. The growth of the proctodeum has thus advanced faster than that of the stomodeum, as no communication has yet developed between the stomodeum and the forward end of the intestine. The opening between the mid-intestine and the end-intestine is, however, closed again before the birth of the larva and remains so during the larval life of the animal, a peculiarity of structure which the larva of *Melophagus* shares with that of the honey-bee.

In the animal represented by these figures, the germinal band has extended over the dorsal side, and the back is thus closed. The heart is present in the form of a delicate tube extending from the ganglia allata to the hinder end of the body.

In embryos in this stage of development (and not in any other) a pair of deep invaginations appears in the outer ectoderm below the mouth (Pl. 4, Figs. 24, 25 and 27, *gl. sal.*); these are probably fundamentals of the salivary glands. They are entirely transitory structures.

b. The Involution of the Head.—An important change now takes place in the development of the forward end of the body. The paired discs, which hitherto have consisted of two ectodermic thickenings embracing each a simple, diagonally placed slit (Pl. 4, Fig. 26, *disc. ce.*), now move forward and towards the median line, where the slits finally meet and unite, forming thus a single, transverse, slit-like opening which extends nearly across the embryo. It is only the upper or ectal portions of the invaginations, however, which thus fuse; their inner or ental portions increase very much in volume and depth, though remaining free from each other, and extend posteriorly in the body-cavity to the vicinity of the

cerebral ganglia, with which they lie in contact. The paired discs have thus become a single structure with a single, median, dorsal, anterior opening, backward from which extends an irregularly Y-shaped invagination. Figure 30 (Pl. 5), which represents a sagittal section, shows the median opening and the median portion of the invagination. Figure 31, which represents a parasagittal section, shows one of the branches of the Y-shaped invagination (*dsc. ce.*); and Figure 32, a parasagittal section laterad of the one last mentioned, shows the irregular structure of the disc.

The ventral median disc (Fig. 30, *dsc. ce. m.*) has not changed its position or character, except to become much thicker.

A comparison of the structures of the embryo represented in Figure 22 (Pl. 3) with those of the one represented in Figure 29 (Pl. 4), which is the same as that of the last three figures discussed, shows that the development in the latter has been considerable. The muscle fibres of the sucking tongue are distinctly developed, but the nerve which proceeds from its base to the ganglia allata, and, also, these ganglia themselves, have not changed their character. The paired ventral nerve-cords and the cerebral ganglionic fundaments (Fig. 31) have developed considerably, the former having fused with the median ectodermic ridge, which has now effected a separation from the ectoderm, and thus come to form with the paired nerves a single structure. Neuroblasts are present throughout the entire extent of both ventral and cerebral nerve-masses, but are not present in the ganglia allata nor in the median nerve proceeding from it. It will also be noticed that the anus has shifted its position from the hinder end of the animal to the ventral side near the hinder end of the mid-intestine, the position it occupies in the larva. A communication has also appeared between the stomodeum and the intestine (Fig. 30).

The involution of the head of the embryo now takes place. An ectodermic fold starts back of the cephalic discs, both dorsally and ventrally (Pl. 5, Fig. 30), and grows rapidly forward towards and over the mouth. The mouth, together with the ventral disc (*dsc. ce. m.*) just below it, the muscular tongue (*lng.*), and the common opening of the dorsal discs (*of. m.*) just above it, is rolled in by this process. A new mouth is thus formed (Pl. 6, Fig. 34, *or.*), and back of it a new portion of the digestive tract (*phy.*), the so-called pharynx of Weismann and Van Rees, described by them in the muscidian larva.

The cephalic imaginal discs now grow rapidly, and soon attain the form which characterizes them in the young larva. The median, ventral disc has begun to invaginate (Pl. 6, Fig. 34, *dsc. ce. m.*), and a cross-section through this region (Pl. 6, Figs. 36 and 37, *dsc. ce. m.*) shows that the invagination is paired. (Compare these cross-sections with Figure 34, where the positions of the cross-sections shown in Figures 36-44 are indicated by the corresponding numbers, 36-44.) The later history of this disc (see Pratt, '93) shows that these paired outgrowths of the ventral invagination develop during the larval period into deep pockets, that a long projection springs from the bottom of each of them, and that subsequently the pockets fuse in the median plane and the projections develop into the proboscis of the imago.

The muscular sucking tongue is now an internal organ (as may be seen in Figures 34, 37 and 38), and projects free into the pharynx. Figure 39 shows the base of the sucking tongue where it is continuous on each side with the pharyngeal wall. The open space dorsal to it is the forward end of the median portion of the lumen of the dorsal discs (*of. m.*), where it communicates with the pharynx. In the stage of development represented by Figure 30 (Pl. 5), this opening (*of. m.*) leads to the outside of the animal's body. The paired nervous masses below the oesophagus are portions of the circum-oesophageal or cerebral commissures (Fig. 39, *coms. cb.*). The section shown in Figure 40 (Pl. 7) also passes through the base of the sucking tongue. The median portion of the fused dorsal discs (*dsc. ce.*) is much broader here, extending quite across the embryonic body, while between it and the oesophagus (*oe.*) are the muscle-mass of the tongue (*lng.*) and the cerebral nerve-mass (*gn. cb.*). The latter is in close contact with the ventral surface of the disc, and with the tongue muscles quite encloses the oesophagus. Figure 41 represents a section made immediately back of the sucking tongue. The median portion of the fused dorsal discs (*dsc. ce.*) is still shown, and between it and the oesophagus are the median nerve (*n. m.*) — which joins the sucking tongue with the ganglia allata — and the two cerebral nerve-masses (*gn. cb.*). Figure 42 shows a section considerably farther back (compare Fig. 34), passing through the paired portions of the dorsal discs (*dsc. ce.*), and also exhibiting the structures seen in the previous section. The next figure (Fig. 43) shows the paired portions of the dorsal discs (*dsc. ce.*) distinct from each other, though still in contact with the

cerebral nerve-masses (*gn. cb.*), as is also shown in the parasagittal section (Pl. 5, Fig. 33). The ganglia allata (*gn. ala.*) and their fusion to form the median nerve are shown in Figure 43. The forward end of the heart (*cr.*) is also cut. Figure 44 represents a section posterior to the dorsal discs and through the hinder part of the ganglia allata. Mesoderm does not make its appearance in the cephalic discs, nor do nerves or tracheae enter them.

The process of the involution of the embryonic head of *Melophagus*, by which the ventral cephalic disc, the sucking tongue, and the median opening of the dorsal cephalic discs, are changed from external to internal organs, and the head of the animal telescoped into the thorax, is really the final act of a longer operation. The head of the embryo, which, in my opinion, is represented by the head-fold of the germinal band, begins to disappear when the stomodaeum begins its migration towards the anterior end of the embryo. The involution of the head has been observed in only one other representative of the brachycerous Diptera besides *Melophagus*, viz. in *Musca vomitoria* by Weismann ('64). Here the disappearance of the head is also a gradual process. The embryonic head gradually grows shorter and at the same time loses its segmentation, its posterior edge moves forward until finally its anterior portion invaginates into the mouth, forming the so-called larval pharynx. The dorsal cephalic discs then appear as appendages of the dorsal pharyngeal wall. But Weismann did not observe the method by which these structures originate.

2. *The Thoracic Discs.*—Six pairs of thoracic imaginal discs make their appearance in the embryo of *Melophagus*. Three pairs are dorsal and three pairs ventral, a dorsal and a ventral pair belonging to each of the pro-, meso-, and metathoracic segments, respectively. The three ventral pairs give rise during metamorphosis to the three pairs of imaginal legs; the dorsal metathoracic pair to the rudiments of the balancers, and the dorsal meso- and prothoracic pairs to no adult structures, they being rudimentary structures. All of these discs first appear late in the embryonic life of the insect; namely, at about the time of the involution of the head, — at a time when the formation of the dorsal cephalic discs is practically complete, when the back of the embryo is closed, and the wall of the intestinal tract is formed.

The earliest appearance of the thoracic discs figured is that shown for the embryo represented in Figure 32 (Pl. 5), in which the

involution of the head is in progress. Three pairs of thickenings of nearly equal size appear in the ventral ectoderm of the forward end of this embryo. In the next stage shown (Pl. 6, Fig. 35), in which the involution of the head is completed, these thickenings have begun to invaginate, and three additional pairs of thickenings have made their appearance in the dorsal ectoderm at the forward end of the embryo. Only the dorsal prothoracic thickening appears in Figure 35; it lies immediately in front of the dotted line leading from the letters *dsc. ce.* The invagination of each ventral disc begins at its posterior border, as shown in the ventral meta-thoracic disc in Figure 35; then the anterior border sinks in, as shown in the mesothoracic disc in this figure; finally the entire disc sinks beneath the surface, as is shown in the prothoracic disc in the same figure. As this figure clearly indicates, the invagination of the three discs is not simultaneous, but the more anterior the disc the earlier the invagination. Complete invagination rapidly follows (Pl. 7, Fig. 45); the disc at once separates itself from the ectoderm, and the opening made in the ectoderm by the invagination closes (Pl. 7, Fig. 46). It is while the discs are in this condition that the embryo leaves the egg-envelopes, and the discs remain in this condition during the entire larval life of the insect.

The dorsal thoracic discs do not invaginate during the embryonic life of the animal. The meso- and metathoracic discs invaginate in the young larva, and become detached from the ectoderm, as do the ventral discs (Pl. 7, Fig. 46). The prothoracic discs do not advance beyond the stage of development represented by figure 45, but remain thick-walled pockets of the ectoderm. They are also lined with a cuticula, continuous with that of the rest of the larval ectoderm, and the different moultings take place from the pockets as from the rest of the insect. In my preliminary paper (Pratt, '97) I have stated that the dorsal prothoracic discs have a larval origin, but later examination of the material has shown this to be an error. As is the case of the cephalic discs, mesoderm does not appear in the thoracic discs during the embryonic life of the insect, nor do nerves or tracheae enter them.

3. *The Discs of the External Genitalia.* — These discs first appear in the embryo shortly before it leaves the egg-membranes. Two pairs of ectodermal thickenings then appear immediately in front of the anus, — a larger posterior and a smaller anterior pair. The former lie just in front of, and partly embracing,

the anus and rectum (Pl. 2, Fig. 48, *dsc. gen. p.*), and the latter immediately in front of it.

These two pairs of discs do not make their appearance simultaneously, the larger, posterior pair being the first to appear. These have the form of two invaginations, one on each side of the anus (Fig. 48), which project forward and fuse on the ventral (anterior) side of the end-intestine, forming a single flattened sac, which partly encircles it (Fig. 49, *dsc. gen. p.*). At its anterior end this sac separates into two parts, being in this region again paired (Fig. 50, *dsc. gn. p.*). It is in the outer ectoderm at this point that the anterior discs finally make their appearance in the form of a pair of ectodermal thickenings (Fig. 50, *dsc. gn. a.*). These do not, however, develop further in the embryo; but in the larva they assume a sac-like form and are detached from the ectoderm. A description of the development of these discs in the larva has already been published (Pratt, '93).

4. *The Discs of the Internal Organs.*—The imaginal discs of the internal organs and of the abdominal hypodermis do not appear during the embryonic life of the insect.

METHODS.

The greater part of this investigation was carried on in the Zoological Laboratory of Harvard University under the direction of Prof. E. L. Mark. It was completed at Haverford College. Most of the material was obtained in Germany, but a portion of it came from the vicinity of Cambridge, Mass., and of Haverford, Pa.

The eggs were obtained by dissection from the maternal uterus, in which they develop. It was found to be impossible to remove them in the fresh condition without injury, on account of the extreme delicacy of the chorion. Consequently, in each case the mother insect was killed by decapitation; the abdomen was slit open and then plunged into a warm corrosive-sublimate solution. This fixed the egg, and at the same time hardened it so that it could be removed from the uterus. Most of the staining was done with borax carmine, which was found sufficient for all ordinary purposes, but Mayer's acid carmine and Ehrlich's haematoxylin also were used.

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EXPLANATION OF PLATES.

All figures are from preparations of *Melophagus ovinus* L., and were made with the aid of a camera lucida. The mesoderm and organs derived from it are colored blue, the yolk yellow.

ABBREVIATIONS.

<i>a.</i>	anterior.	<i>i'vag. tr.</i>	tracheal invagination.
<i>am.</i>	amniotic rudiment.	<i>la. g.</i>	germinal plate.
<i>an.</i>	anus.	<i>lng.</i>	sucking tongue.
<i>bl'drm.</i>	blastoderm.	<i>mr'py.</i>	micropyle.
<i>chn.</i>	chorion.	<i>ms'drm.</i>	mesoderm.
<i>coel.</i>	body-cavity.	<i>n. m.</i>	median nerve.
<i>coms. cb.</i>	cerebral commissures.	<i>n. v.</i>	ventral nerve chord.
<i>cr.</i>	heart.	<i>nl.</i>	segmentation nuclei.
<i>cras. stmd.</i>	stomodeal thickening.	<i>nl. vt.</i>	yolk nuclei.
<i>crs. ms'drm.</i>	mesodermic ridge.	<i>oe.</i>	oesophagus.
<i>crs. m-v.</i>	mid-ventral ectodermic ridge.	<i>of. m.</i>	median opening of paired cephalic disc.
<i>d.</i>	dorsal.	<i>or.</i>	mouth.
<i>dsc. al.</i>	wing disc.	<i>p.</i>	posterior.
<i>dsc. ce.</i>	paired cephalic disc.	<i>phy.</i>	pharynx.
<i>dsc. ce. m.</i>	median cephalic disc.	<i>pli. ca.</i>	tail-fold.
<i>dsc. gen. a.</i>	anterior genital disc.	<i>pli. ce.</i>	head-fold.
<i>dsc. gen. p.</i>	posterior genital disc.	<i>prd.</i>	proctodeum.
<i>dsc. pd. 1.</i>	prothoracic leg disc.	<i>stmd.</i>	stomodeum.
<i>dsc. pd. 2.</i>	mesothoracic leg disc.	<i>st. pr'pl. pi.</i>	peripheral protoplasmic layer.
<i>dsc. pd. 3.</i>	metathoracic leg disc.	<i>sul. m-v.</i>	mid-ventral groove.
<i>en'drm.</i>	endoderm.	<i>tae. ms'drm.</i>	mesodermic bands.
<i>gl. sal.</i>	salivary glands.	<i>tb. mpg.</i>	Malpighian tubules.
<i>gn. ala.</i>	ganglia allata.	<i>tr.</i>	trachea.
<i>gn. cb.</i>	cerebral ganglia.	<i>trt. pr'pl.</i>	protoplasmic paths.
<i>gn. f.</i>	ganglion frontale.	<i>v.</i>	ventral.
<i>gran. vt.</i>	yolk granules.		

PLATE 1.

- Fig. 1. Longitudinal section of a segmenting egg, in a plane nearly coinciding with the sagittal plane of the embryo. $\times 78$.
- Fig. 2. Similar section of a somewhat older segmenting egg. $\times 78$.
- Fig. 3. A portion of the section shown in the preceding figure, seen under a higher magnification. $\times 760$.
- Fig. 4. Sagittal section of a segmenting egg in which all parts of the peripheral layer of protoplasm are occupied by nuclei. $\times 78$.
- Fig. 5. A portion of the preceding section seen under a higher magnification, many of the nuclei in process of division; the peripheral layer of protoplasm with shallow grooves surrounding the nuclei. $\times 760$.
- Fig. 6. A portion of a section of a segmenting egg showing the deepening of the grooves in the peripheral layer of protoplasm to form the cells of the developing blastoderm. $\times 760$.
- Fig. 7. A portion of a section showing the completely formed blastoderm. $\times 875$.

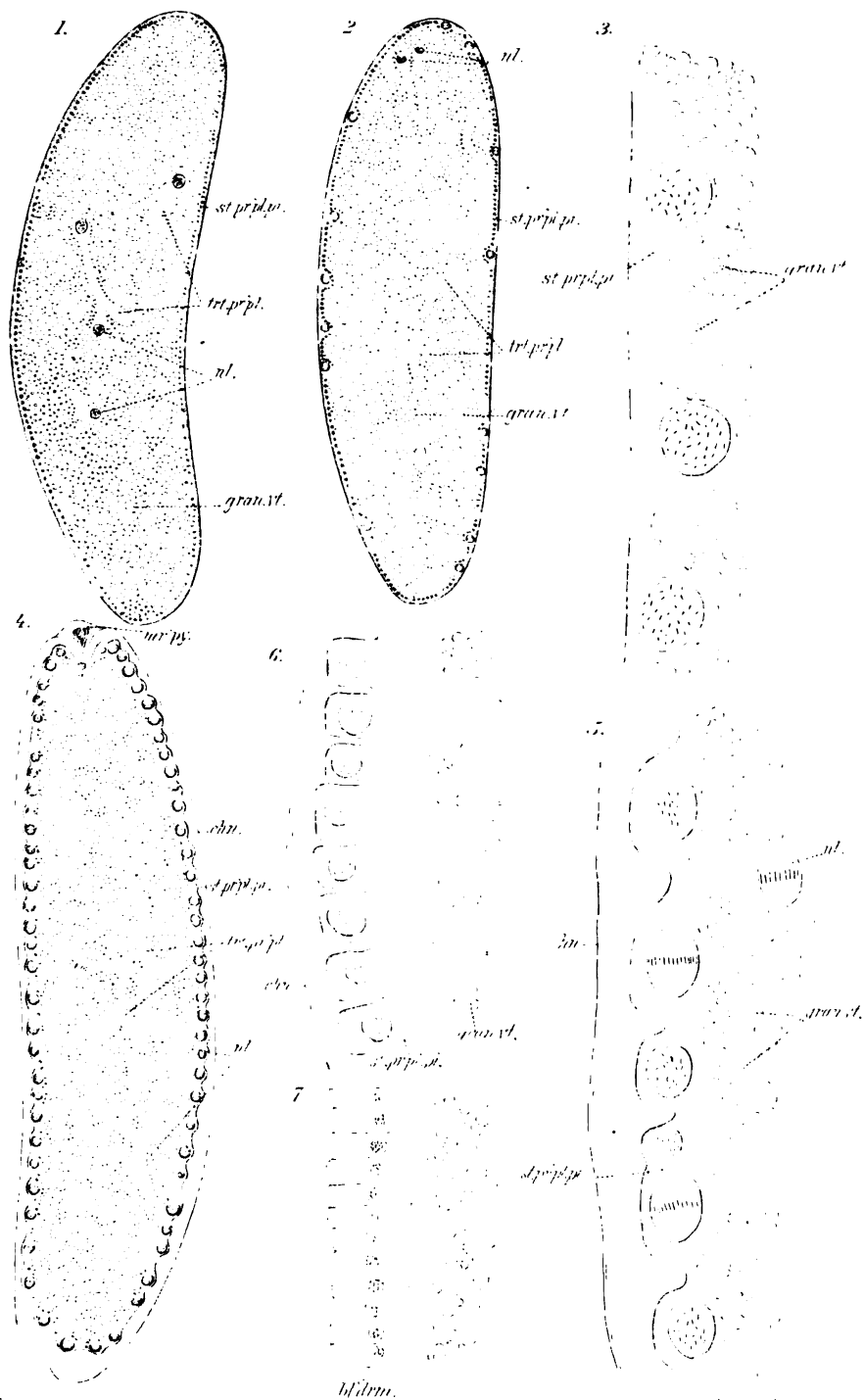
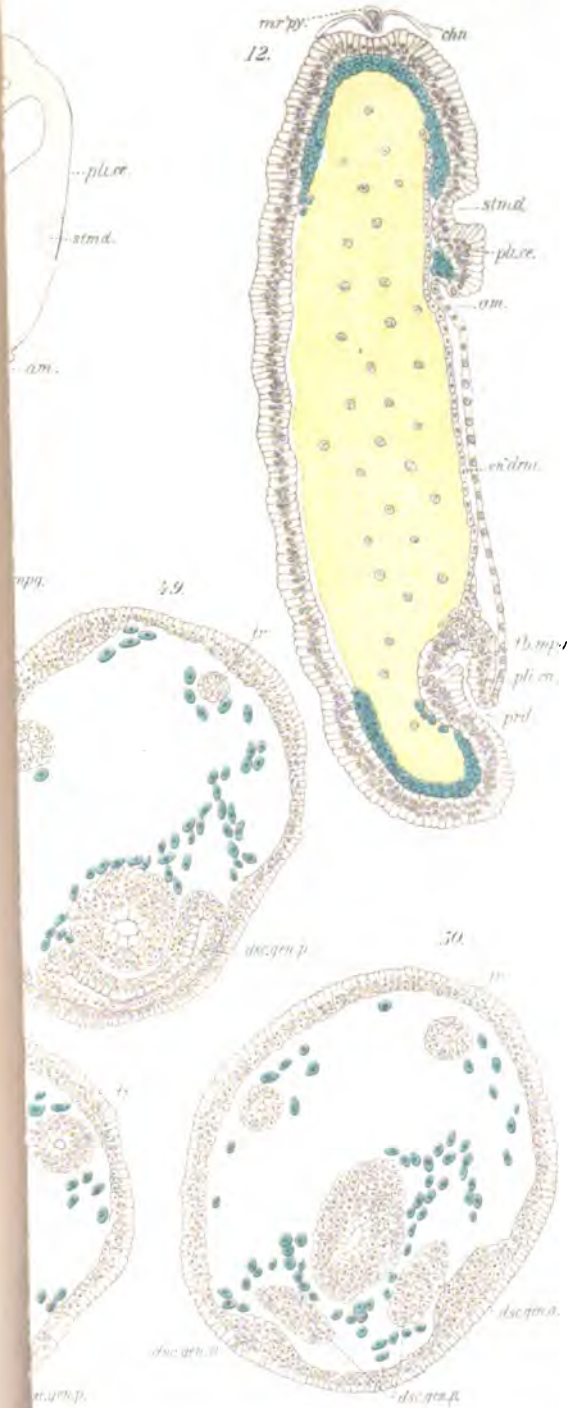


PLATE 2.

- Fig. 8. Cross-section of an embryo showing the origin of the mesoderm. $\times 130$.
- Fig. 9. Sagittal section of an embryo showing the formation of the head- and tail-folds. $\times 100$.
- Fig. 10. Sagittal section of an embryo showing formation of proctodeum. $\times 100$.
- Fig. 11. Dorsal aspect of an embryo in which both proctodeum and stomodeum have been formed. $\times 100$.
- Fig. 12. Semi-diagrammatic sagittal section of an embryo in which both proctodeum and stomodeum have been formed. $\times 100$.
- Fig. 13. Surface view, lateral aspect, of an embryo of the same stage as that of Fig. 12. $\times 100$.
- Fig. 14. Cross-section through the stomodeum of an embryo of about the same age as that shown in Figs. 12 and 13. $\times 130$.
- Fig. 15. Cross-section through the middle of the same embryo as the one shown in the preceding figure. $\times 130$.
- Fig. 16. Cross-section through the proctodeum of the same embryo as that shown in Fig. 14. $\times 130$.
- Fig. 48. Cross-section of an old embryo, passing through the anus and showing the invaginations of the posterior genital discs. $\times 220$.
- Fig. 49. Cross-section passing through the end-intestine and middle portion of the genital discs. From the same embryo. $\times 220$.
- Fig. 50. Cross-section passing through the anterior genital discs of the same embryo. $\times 220$.

PLATE 2.



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PLATE 3.

- Fig. 17. Surface view, dorsal aspect, of the head-fold of an embryo, showing the first appearance of the cephalic imaginal discs. $\times 100$.
- Fig. 18. Cross-section through the stomodeum of an embryo somewhat older than that represented in Fig. 17. $\times 130$.
- Fig. 19. Cross-section of the same embryo as that shown in Fig. 18, taken at some distance further back, showing the cephalic discs where they are deepest. $\times 130$.
- Fig. 20. Cross-section through the middle of the same embryo. $\times 130$.
- Fig. 21. Cross-section through the proctodeum of the same embryo. $\times 130$.
- Fig. 22. A somewhat oblique, but nearly sagittal, section of an embryo, the stomodeum of which has reached a terminal position. $\times 130$.

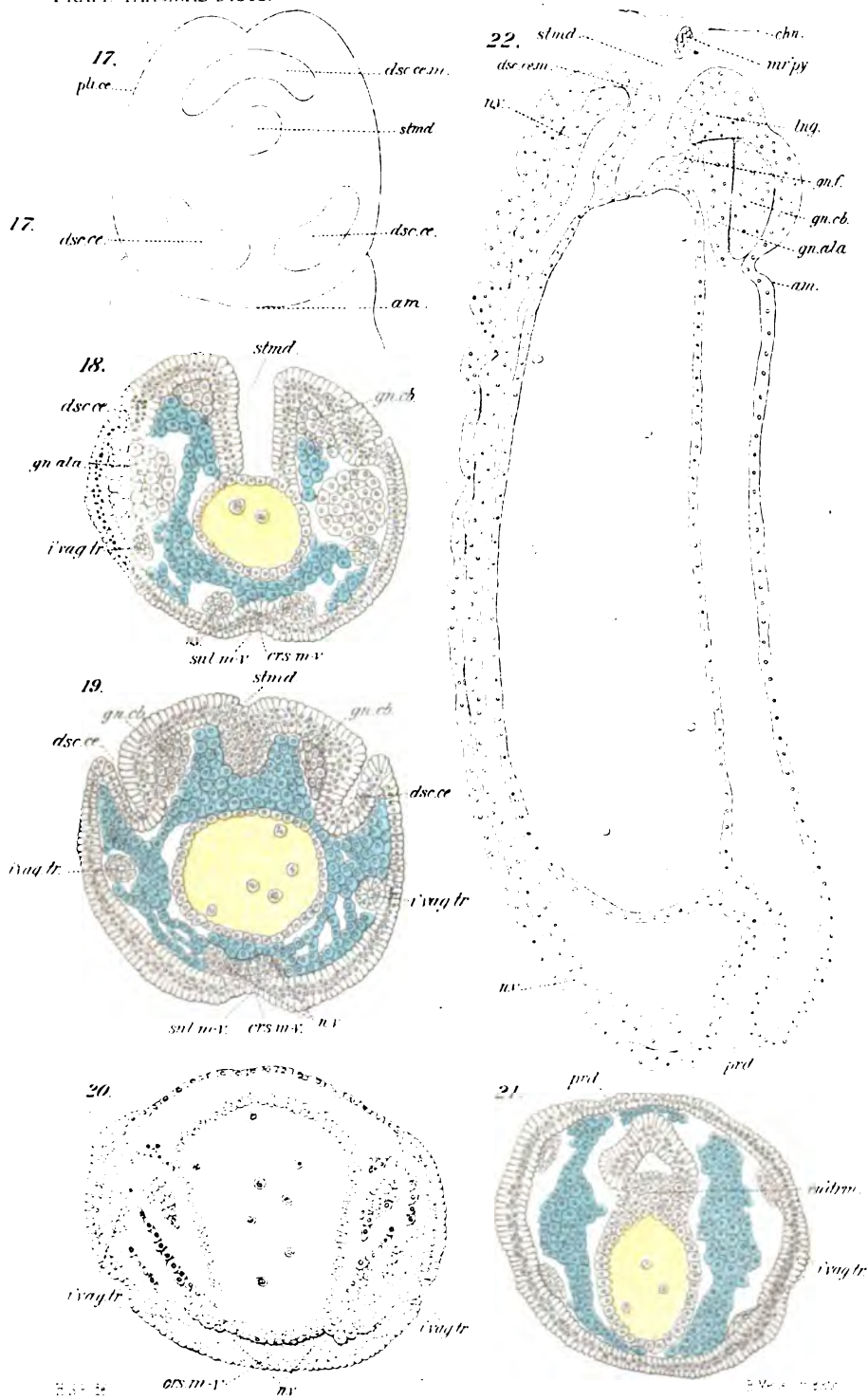
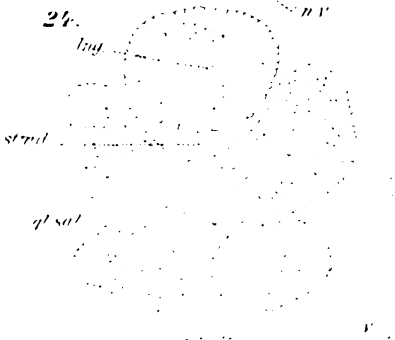
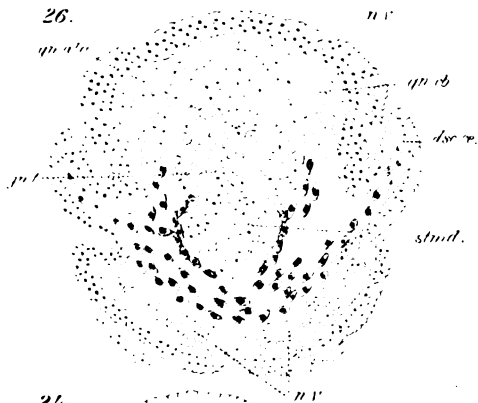
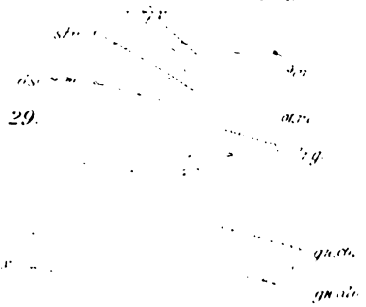
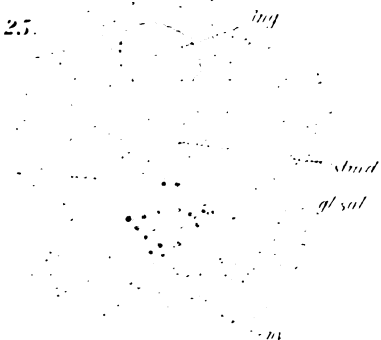


PLATE 4.

- Fig. 23. Parasagittal section of the same embryo as that shown in the preceding figure. $\times 130$.
- Fig. 24. Cross-section through the extreme anterior end of an embryo somewhat older than that shown in the two preceding figures. $\times 200$.
- Fig. 25. Cross-section through the base of the sucking tongue of the same embryo. $\times 200$.
- Fig. 26. Cross-section through the cephalic discs of the same embryo. $\times 200$.
- Fig. 27. Surface view of a wax model representing the anterior end of an embryo of about the same age as that shown in Figs. 22 and 23. $\times 300$.
- Fig. 28. Surface view, lateral aspect, of the head end of an embryo of the same age as that shown in Figs. 22 and 23. $\times 200$.
- Fig. 29. A slightly oblique sagittal section of an embryo, older than that shown in Fig. 22, in which the involution of the head has begun. $\times 130$.



28.

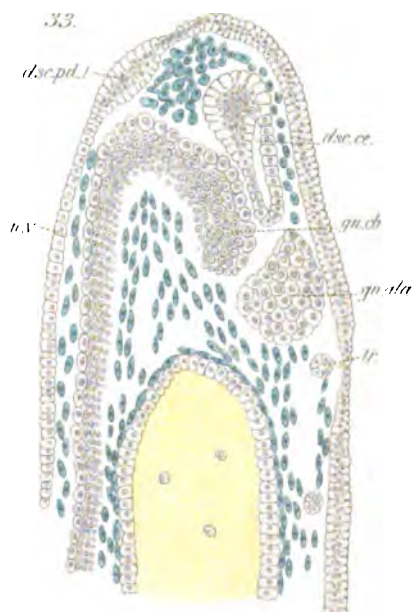
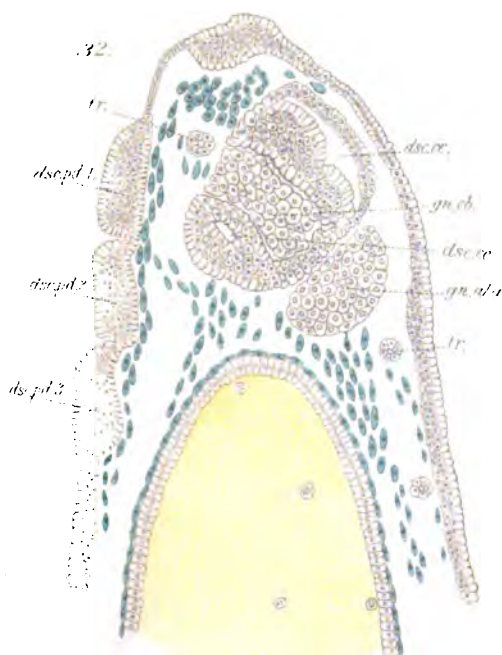


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PLATE 5.

- Fig. 30.** Anterior portion of the section represented in Fig. 29, seen under a higher magnification. $\times 200$.
- Figs. 31 and 32.** Parasagittal sections of the same embryo, Fig. 32 being from the more lateral section. $\times 200$.
- Fig. 33.** Parasagittal section of the same embryo as that shown in Figs. 34 and 35. It is more lateral in position than Fig. 35. $\times 200$.



H.S.P. del.

G. M. Smith sculp.

PLATE 6.

- Fig. 34. A slightly oblique sagittal section of an embryo in which the involution of the head is completed. $\times 200$.
- Fig. 35. Parasagittal section intermediate in position between those of Figs. 33 and 34 and from the same embryo as those figures. $\times 200$.
- Figs. 36-39. Cross-sections of the forward end of an embryo of about the same age as that shown in the preceding figures. The region of the embryo from which each of the sections is taken is indicated in Fig. 34 by the number of the figure representing the section. $\times 200$.

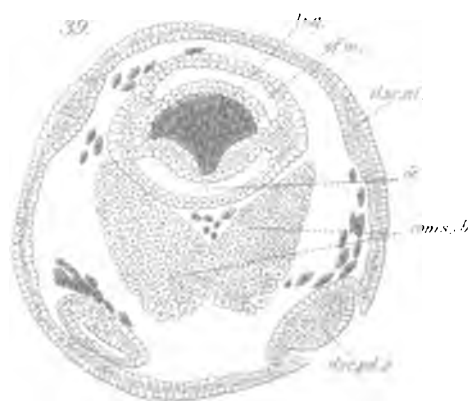
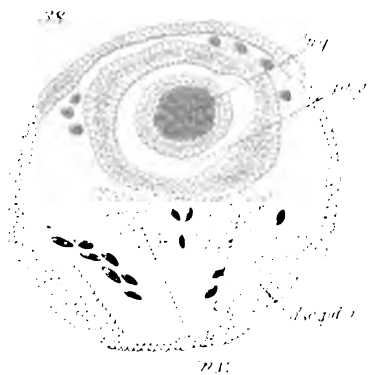
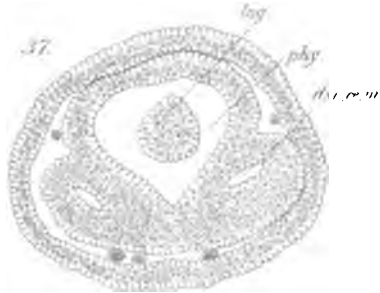
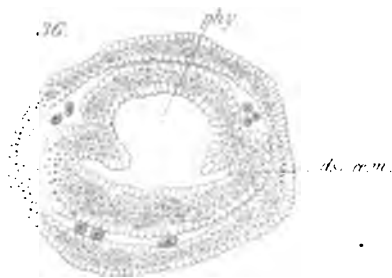
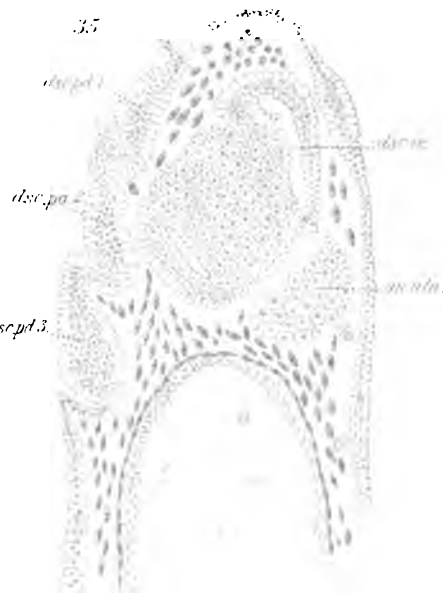
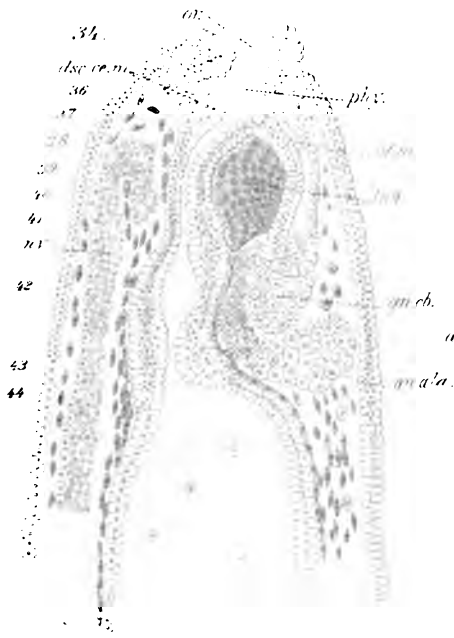


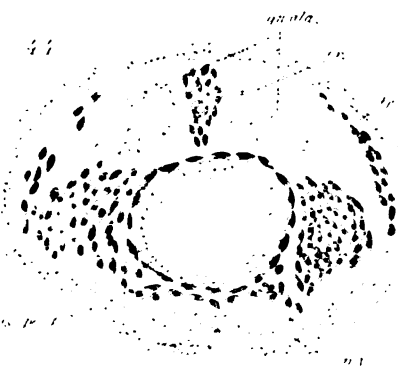
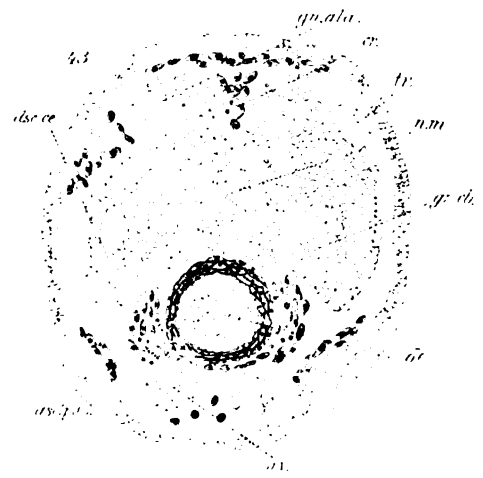
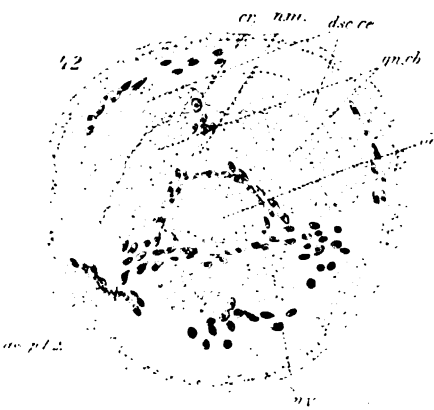
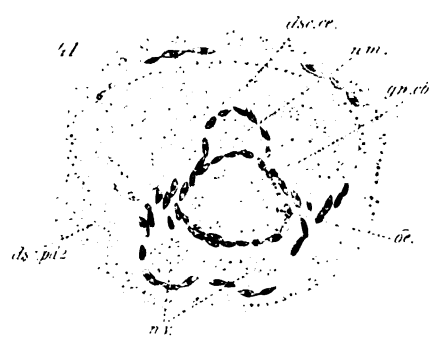
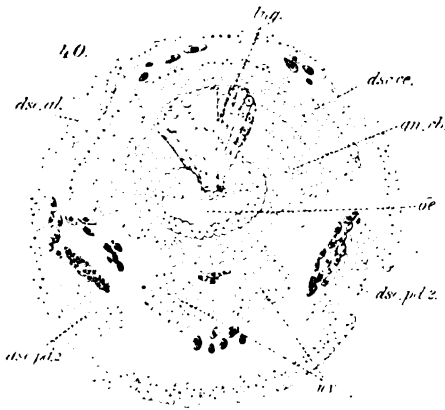
PLATE 7.

Figs. 40–44. Cross-sections of the forward end of the same embryo as that shown in the preceding four figures. The region of each section is indicated in Fig. 34, Pl. 7, by the number of the figure which represents the section. $\times 200$.

Fig. 45. Frontal section passing through an invaginating thoracic disc. $\times 340$.

Fig. 46. Similar section of a completed thoracic disc. $\times 340$.

[There is no Figure 47. Figures 48–50 are on Plate 2.]



No. 14. — *Glacial Erosion in France, Switzerland and Norway.*

By WILLIAM MORRIS DAVIS.

Introductory. — Eighteen years ago I presented to this Society an essay on Glacial Erosion, in which my own observations were supplemented by a review of all that I could find written on the subject, in the hope of reaching some safe conclusion regarding what was then (as it is still) a mooted question. Although recognizing effective erosion to depths of "a moderate number of feet" where ice pressure was great and motion was rapid, in contrast to deposition where pressure and motion were reduced and where the amount of subglacial drift was excessive, I could not at that time find evidence to warrant the acceptance of great glacial erosion, such as was advocated by those who ascribed Alpine lakes and Norwegian fiords to this agency. In a retrospect from the present time, it seems as if one of the causes that led to my conservative position were the extreme exaggeration of some glacialists, who found in glacial erosion a destructive agency competent to accomplish any desired amount of denudation — an opinion from which I recoiled too far. Since the publication of my previous essay I had gradually come to accept a greater and greater amount of glacial erosion in the regions of active ice motion; but in spite of this slow change of opinion, the maximum measure of destructive work that, up to last year, seemed to me attributable to glaciers was moderate; and it was therefore with great surprise that I then came upon certain facts in the Alps and in Norway which demanded wholesale glacial erosion for their explanation. The desire of some years past to revise and extend my former essay then came to be a duty, which it is the object of this paper to fulfil.

My former revision of the problem divided the arguments for glacial erosion under four headings: observations on existing glaciers and inferences from these observations; the amount and arrangement of glacial drift; the topography of glaciated regions; and the so-called argument from necessity, — that is, the belief that glaciers must have done this and that because nothing else

competent to the task could be found. It is not possible for me at present to review all the new material pertinent to the whole problem; attention can be given here chiefly to a few examples under the third heading.

A Glaciated Valley in Central France. — It is evident that, if it were possible to obtain a definite idea of the preglacial topography of a glaciated district, the amount of glacial work might be readily determined as the difference between the preglacial and the present form; independent evidence sufficing to prove that general denudation of the rocky crust in the brief postglacial epoch had been inconsiderable. This method leads one to conclude that in general the topography of southern New England has not been strongly modified by glacial action; for we find here on the whole the same maturely dissected upland that prevails in regions of similar structure outside of the glacial boundary; the uplands being explained as parts of an uplifted peneplain of late Mesozoic date, and the valleys as the work of ordinary erosion in a part of Tertiary time: but this method of measuring glacial erosion by dating topographic forms had not been developed twenty years ago. Strong glacial erosion may, however, be expected in New England where ice motion was locally accelerated, as through the notches of the White Mountains. Again, in the glaciated area of the Central Plateau of France, I had opportunity in January, 1899, of seeing a valley that had been locally modified to a determinate amount by a glacier that once descended northwest from the Cantal along the valley of the Rhue to the junction of the latter with the Dordogne. Outside of the glaciated area, the valleys of the plateau — an uplifted and sub-maturely dissected peneplain, mostly of crystalline rocks — frequently follow incised meandering courses, in which the steep concave slopes are regularly opposed to the gentler convex slopes; the latter being spur-like projections of the uplands, advancing alternately from one and the other side of the valley. Valleys of this kind are singularly systematic in form, as the result of the combined downward and outward cutting by their streams which, already winding or meandering when the erosion of the valleys began, have increased the width of their meander belt while they deepened their valleys. On entering the glaciated valley of the Rhue, it is found that the regularly descending spurs of the non-glaciated valleys are represented by irregular knobs and mounds, scoured on their up-stream and plucked on the down-stream side; and that the cliffs formed where the spurs are

cut off, as in Fig. 1, are sometimes fully as strong as those which naturally stand on the opposite side of the valley. The spurs generally remain in sufficient strength to require the river to follow its preglacial serpentine course around them, but they are sometimes so far destroyed as to allow the river to take a shorter course



Fig. 1. The glaciated valley of the Rhue.

through what was once the neck of a spur.¹ The short course is not for a moment to be confounded with the normal cut-offs through the narrowed necks of spurs, such as are so finely exhibited in the meandering valleys of the Meuse and the Moselle. The short courses are distinctly abnormal features, like the rugged knobs to which the once smooth-sloping spurs are now reduced.

It was thus possible in the valley of the Rhue to make a definite restoration of preglacial form, and to measure the change produced by glaciation. The change was of moderate amount, but it was highly significant of glacial action, for it showed that while a slender, fast-flowing stream of water might contentedly follow a serpentine course at the bottom of a meandering valley, the clumsy, slow-moving stream of ice could not easily adapt itself to so tortuous a path. The more or less complete obliteration of the spurs was the result of the effort of the ice stream to prepare for itself a smooth-sided trough of slight curvature; and if the rocks had been weaker, or if the ice had been heavier, or if the glacial period of the Cantal had lasted longer, this effort might have been so successful as to have destroyed all traces of the spurs. Fortunately the change actually produced, only modified the spurs, but did not entirely

¹ The short-cuts are sometimes narrow gorges incised in the half-consumed spurs; and in such cases, the displacement of the Rhue from its former roundabout course is probably to be explained by constraint or obstruction by ice.

destroy them; and their rugged remnants are highly significant of what a glacier can do.

Rocky Knobs in Glaciated Areas.—On thus generalizing the lesson of the Rhue, it is seen that just before the complete obliteration of the spurs some of their remnant knobs may be isolated from the uplands whence these preglacial spurs descended. It is out of the question to regard the ruggedness of such knobs as an indication of small change from their preglacial form, as has been done by some observers. The ruggedness is really an indication of the manner in which a glacier reduces a larger mass to smaller dimensions, by plucking on the down-stream side as well as by scouring on the up-stream side. It is possible that knobs in other glaciated valleys than that of the Rhue may be of this origin; they should then be regarded not as standing almost unchanged and testifying to the incapacity of glacial erosion, but as surviving remnants of much larger masses, standing, like monadnocks above a peneplain, as monuments to the departed greater forms. The two knobs at Sion (Sitten) and the Maladeires, all detached from Mont d'Orge in the upper valley of the Rhone, the hills of Bellinzona in the valley of the Ticino, the rocks of Salzburg where the Salzach emerges from the Alps, and even the Borromeo islands in Lake Maggiore, may perhaps be thus interpreted. Rugged as these knobs may be on the down-stream side, it would be an unreasonable contradiction of the conclusions based on observations of many kinds to maintain that their ruggedness was of preglacial origin.

The ice stream from the Cantal at one time expanded sufficiently to flood the uplands bordering the valley of the Rhue,¹ where it produced changes of a most significant kind. The neighboring unglaciated uplands are of systematic form; broad, smoothly arched masses rise, round-shouldered, between the narrow valleys that are incised beneath them; the uplands are as a rule deeply soil-covered, and bare ledges prevail only on the stronger slopes of the young valleys that have been eroded since the peneplain was raised to its present upland estate. But within the glaciated area near the Rhue, the broadly rounded forms of the uplands are replaced by a succession of most irregular rocky knobs, from which the preglacial soils have been well scoured away, as in Fig. 2. This seems to be a form most appropriate to glacial action on a surface that had been

¹ According to Boule ('96), the glaciation of the uplands and of the valleys was separated by an interglacial epoch, but I did not have occasion to inquire particularly into this aspect of the problem.

weathered to variable depths in preglacial time. The ice action sufficed to rasp away the greater part of the weathered material, and to grind down somewhat the underlying rock, often giving the knobs a rounded profile; but it did not nearly suffice to reduce the



Fig. 2. Glaciated knobs on the Central Plateau of France.

rocky surface to an even grade. The ice action seems here to have resembled that of a torrent which might sweep away the waste on a flood plain and lay bare and erode the rock ledges beneath; but whose duration was not sufficient to develop a graded floor appropriate to its current.

Another example of this kind seems to occur where the huge glacier of the Inn, escaping from its well enclosed channel within the mountains, once spread forward in a great fan of ice over the foot-hills at the northern border of the Alps and crept out upon the piedmont plain. The glance that I had at this foot-hill district from a passing train gave me the impression that its ruggedness was much greater than usually obtains along the mountain flanks; as if the rolling hills of preglacial time had been scoured to an increasing roughness by an overwhelming ice-flood that would, if a longer time of action had been permitted to it, have worn down all the inequalities to a smooth, maturely graded floor.

The Valley of the Ticino. — My first entrance into the Alps last year was from the south by the valley of the Ticino. Thirty-one years before I had followed the same valley and admired its bold sides and its numerous waterfalls; but at that time nothing was noticed that seemed inappropriate to the general idea of the erosion

of valleys by their rivers. Thirty years is a long enough time for one to learn something new even about valleys, and on my second visit it was fairly startling to find that the lateral valleys opened on the walls of the main valley of the Ticino five hundred feet or more above its floor, and that the side streams cascaded down the steep main-valley walls in which they have worn nothing more than narrow clefts of small depth. This set me wondering, not only as to the meaning of so peculiar an arrangement of valleys and streams, but also as to the reason why so peculiar an arrangement should not have sooner attracted attention as an exceptional characteristic of Alpine topography. Playfair long ago, when describing the relation of side valleys to their trunk, showed clearly that they had

“such a nice adjustment of their declivities that none of them join the principal valley either on too high or too low a level: a circumstance which would be infinitely improbable if each of these vallies were not the work of the stream that flows in it” (‘02, 102); yet the whole course of the passing century has hardly sufficed to make full application of this law. So much latitude is usually allowed in the relation of branch and trunk valleys that hundreds of observers, many of whom must have been cognizant of Playfair’s law, have made no note



Fig. 3. Val d'Ossogna, a hanging lateral valley of the Ticino.

of the extraordinary exceptions to it that prevail in the glaciated valleys of the Alps. Even the most pronounced advocates of glacial erosion, with a few exceptions to be noted below, have been silent regarding the remarkable failure of adjustment between the declivities of lateral and main glaciated valleys. Indeed, in reviewing the writings of those who have accepted a

large measure of glacial erosion, one must be struck with the undue attention that they have given to lake basins and the relative inattention to valleys. This disproportion is probably to be explained as a result of the greater contrast that prevails between a river and a lake than between a river and its branch; it is perhaps for this reason that the attention of geologists and geographers has generally been directed to the origin of lakes rather than to the relation of branch and trunk streams, even when the former cascade from their lateral valleys into the main valley. That glacial erosionists made so little claim for the general deepening of glaciated valleys while they demanded a great deepening of those parts of valleys which have been scoured down to form lake basins, has always seemed to me a difficulty in the way of accepting the demanded measure of lake-basin erosion; and this difficulty was supported by the well-attested observation that the side slopes of glaciated valleys manifest no marked or persistent increase of declivity in passing from above to below the limit of glaciation. If glaciers had scoured

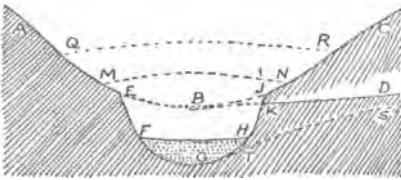


Fig. 4. Section of a glaciated valley.

out deep lake basins, like those of Maggiore and Geneva, they ought to have significantly deepened the valleys up-stream from the lakes; and if the valleys were thus significantly deepened, it seemed as if their slopes should be steeper below than above the limit of glacial

action. The denial of the latter requisite seemed to me to carry with it the denial of the two preceding suppositions.

Features of Strongly Glaciated Valleys.—It is true that the uppermost limit of glaciation, Q R, Fig. 4, in Alpine valleys is not attended by a persistent change in the steepness of the valley sides, A E, C J; but on descending well within the glaciated valley, a very strong change may usually be found in the slope of the valley walls. The larger valleys, once occupied by heavy glaciers from the lofty central snow fields, are characterized by "basal cliffs," E F, J H, that rise several hundred or even a thousand feet above their broad floors, and thus enclose what may be called a "bottom trough," E F H J, half a mile or a mile wide. The bottom trough of the Ticino, as seen when one looks up stream towards Giornico, is shown in Plate 1, Figure A. The

basal cliffs are comparatively straight-walled; they have no sharp spurs advancing into the valley floor. The rock floor, G, Fig. 4, is buried by gravels, F II, to an unknown depth. It is only from the benches above the basal cliffs that the valley sides flare open with maturely inclined slopes; and it is at a moderate depth beneath the level of the benches at the top of these basal cliffs that the lateral valleys, D K, open on the walls of the main valley.

The bottom trough within the basal cliffs and beneath the lateral valleys seems to be of glacial origin. It is in the first place a characteristic feature of all the larger glaciated Alpine valleys, as I am assured by Professors Penck, Brückner and Richter, with whom the matter was carefully discussed last summer. The non-glaciated valleys manifest no such peculiar form. It is not simply that the terminal portion, J B K, of a lateral valley has been cut off by the glacial widening of the main valley floor; the main valley has been strongly deepened, as is assured by the relation of its floor, F H, to the prolongation of the floor of the lateral valley, K B. The first may be several hundred feet—indeed in some valleys, a good thousand feet—below the second. The lateral valleys must have once entered the main valley at grade, for the flaring sides of the main valley indicate maturity; the side slopes, A E, C J, must have once met at B. Even the lateral valleys have an open V section, proving that their streams had cut down to a graded slope, D B, that must have led them to an accordant junction with the main river. Nothing seems so competent as glacial erosion to explain the strong discordance of the existing valleys.

The lateral as well as the main valleys have been glaciated, but the former do not exhibit changes of form so distinctly as the latter: in the Ticino system the lateral valleys did not, as far as I saw them, seem to have been much affected by glaciation, a fact that may be attributed to the small size of their branch glaciers in contrast with the great volume of the trunk glacier. There is no sufficient evidence that the valley floor between the basal cliffs has been faulted down, after the fashion of a *graben*; for although this origin is advocated by Rothpletz ('98, 237) for the Linththal, the evidence that he adduces for the limiting faults is not agreed to by Alpine geologists in general, and the persistent association of the bottom troughs with the crooked course of pre-existent, maturely open valleys involves special conditions of faulting that cannot be accepted without the strongest evidence.

It is not satisfactory to explain the bottom trough as having been worn out by normal trunk-river erosion, leaving the side streams as it were hanging or suspended above them, for to admit such an origin would be to go counter to all that has been learned regarding the systematic development of valleys. Here it is with regret that I must differ from the opinion of two eminent Swiss geologists who explain the deepening of the main valleys by a revival in the erosive power of the rivers as a result of a regional uplift, while they regard the hanging lateral valleys as not yet accordantly deepened by their smaller streams. It is true that narrow trenches are cut in the floors of the hanging valleys, showing that their streams have made some response to the erosion of the bottom trough in the main valley, and if the bottom trough were a narrow canyon, this relation of trunk and branch streams might be considered normal; but if the breadth as well as the depth of the bottom trough had been acquired by normal river erosion, the side valleys should now, it seems to me, have been trenched much deeper than they are, to some such slope as ST, Fig. 4.

The opinions of Rüttimeyer and Heim on this question are as follows:—Rüttimeyer gave an excellent account of hanging lateral valleys thirty years ago in his description of the valley of the Reuss ('69, 13-24). He recognized benches or *Thalstufen* on each side of the valley above the basal cliffs of the existing bottom trough, and regarded them as the remnants of a former, wide open valley floor. Side valleys of moderate fall enter the main valley about at the level of the *Thalstufen*, and their waters then cascade down over the basal cliffs to the Reuss. Glacial erosion is dismissed as incompetent to erode the bottom trough; indeed, the time of glacial occupation of the valley is considered a period of rest—a sort of “pupa stage”—in its development. The discordance of main and lateral valleys is ascribed entirely to the differential erosion of their streams. Heim's views on this matter are to be found in his “*Mechanismus der Gebirgsbildung*” ('78, 1, 282-301) and in an article “*Ueber die Erosion im Gebiete der Reuss*” ('79). He recognizes that the bottom troughs have been excavated in the floors of pre-existing valleys, whose stream lines had been reduced to an even grade (profile of equilibrium, “*Gleichgerichtslinie*”) and whose lateral slopes had been maturely opened. The side streams must at that time have eroded their valleys deep enough to enter the main valley at accordant grade as stated above. Since

then, it is concluded that an elevation of the region has caused a revival (*Neubelebung*) of the main river; and the present greater depth of the main valley is, according to Heim, merely the natural result of this revival, while the smaller side streams have not yet been able to deepen their valleys. The height of the *Thalstufen* or remnants of the former valley floor, seen in the benches above the basal cliffs of the bottom trough, is taken as a measure of the elevation that the mountain mass has suffered.

Apart from the improbability that the deepening of a bottom trough by a revived main river could truncate so many lateral valleys with so great nicety as is repeatedly the case, leaving their streams to cascade down in clefts but slightly incised in the main valley walls, the following considerations lead me to reject the possibility of explaining the discordance between side and main streams by a normal revival of river action.

Relation of Trunk and Branch Valleys. — The general accordance of maturely developed main and lateral valleys in non-glaciated regions, as recognized by Playfair, is today fully established by innumerable observations in many parts of the world. Truly, during the attainment of mature development, it is possible that a large river may outstrip a small branch stream in the work of deepening its valley, but the discordance thus produced can prevail only during early youth; for as soon as the main river approaches grade the further deepening of its valley is retarded, while at the same time the steepened descent of the lateral streams at their entrance into the main valley accelerates their erosive work. Hence, even if a large trunk river has for a time eroded its valley to a significant depth beneath the tributary valleys, this discordance cannot endure long in the history of the river. Examples of such normal discordance are to be found in non-glaciated regions only in the branch streams of rivers that occupy very narrow canyons; and even rivers in canyons sometimes receive their branches at accordant grade, as seems to be usually the case with the Colorado, if one may judge by photographs. The narrow postglacial gorges cut by active streams, habitually receive their branches — when they receive any — from hanging side gorges; and an excellent example has long since been on record in the gorge of Cattaraugus Creek in western New York, where a branch, the Canaserowlie, falls into the main gorge from a side gorge of much less depth. Referring to this, Hall wrote: — “In the more recently excavated channels we find the streams falling over the very edge of the cliff, having produced no perceptible

recession in the margin of the fall" ('43, 380). But however appropriate a discordance of branch and trunk may be in early youth, it cannot endure long enough to be associated with maturely opened main valleys. It should be noted that discordance of side and main valleys may also be found where a large river has lately been turned to a new path, as in the normal progress of the capture of the upper course of one river by the headward gnawing of a branch of another river (see reference to Russell below), or in the new arrangements of drainage lines in a region from which a glacial sheet has lately withdrawn. Furthermore, the valleys of very small wet-weather streams are frequently discordant with the valley of a serpentine river, if they enter it from the upland that is under-cut by the concave bank of the river. But these cases cannot find application in the hanging valleys of the Alps. The hanging valleys that open on sea cliffs, such as those of Normandy, are of course quite another matter.

Overdeepened Main Valleys and Hanging Lateral Valleys.— Now it is characteristic of the bottom troughs of the glaciated Alpine valleys that they are broad-floored; they cannot be described as canyons in any proper sense of that word: the walls are steep enough, but they are too far apart. If the existing breadth of the troughs had been acquired in the ordinary manner by the lateral swinging of the main stream and by the lateral weathering of the walls, the long time required for such a change would have amply sufficed for the lateral streams to cut down their valleys to grade with the main valley; and their persistent failure to do so indicates the action of something else than normal river work in the widening of the main valley. This is the very kernel of the problem.

If a main valley were excavated along a belt of weak rocks, the side valley might stand for some time at a considerable height above the main valley floor. Certain hanging valleys in the Alps seem at first sight to belong to this class, but such is not really the case. For example, where the Linth flows into the Wallen See, the well-defined bottom troughs of the river and of the lake both pass obliquely through a syncline of strong lower Cretaceous limestone, which forms cliffs on their walls. Side streams drain the high synclinal areas; one such stream cascades from the west into the Linth trough back of the village of Näfels; another cascades from the north into the Wallen See near its western end. The first explanation for such falls is that they are normally held up on the resistant limestone; but it should be noted that the bottom troughs

of the Linth and the Wallen See have been cut down and broadly opened in the same limestones. If the troughs were of normal river origin, the side streams also should have by this time trenched the limestones deeply, instead of falling over the limestone cliffs at the very side of the larger troughs. In the Ticino valley where the side streams are most discordant, massive gneisses prevail; the structure is so nearly uniform over large areas that it affords no explanation of the strong discordance between side and main valleys.

It thus seems obligatory to conclude that the bottom troughs of the larger Alpine valleys were deepened and widened by ice action. This belief is permitted by the abundant signs of glacial erosion on the spurless basal cliffs, and required by the persistent association of over-deepened bottom troughs and discordant hanging lateral valleys with regions of strong glaciation. The valley of the Ticino manifests these peculiarities very distinctly, and I have recently described them in some detail in a paper in *Appalachia* (1900).

Subaerial Erosion during the Glacial Period. — It should not be imagined that the glacial erosion of troughs in valley floors was necessarily so rapid that no significant subaerial erosion was accomplished during its progress. Ordinary weathering and down-hill transportation of rock waste must have been in active operation on the valley sides above the border of the ice-filled channels; and the very fact that on the upper slopes of the mountains, pre-glacial, glacial and postglacial erosion was similarly conditioned, makes it difficult to distinguish the work done there in each of these three chapters of time. In the diagrams accompanying this article no indication of change from preglacial to postglacial outline on the upper mountain slopes is indicated, because no satisfactory measure can be given to it.

Lake Lugano. — In the presence of a variety of evidence collected for some years previous to my recent European trip, it had been my feeling that the best explanation offered for the large lakes that occupy certain valleys on the Italian slope of the Alps was that they had resulted from what has been called valley-warping, as set forth by Lyell, Heim and others. It was my desire to look especially at Lakes Maggiore, Lugano and Como with this hypothesis in mind, and to subject it to a careful test by means of certain associated changes that should expectedly occur on the slopes of the neighboring mountains, as may be explained as follows.

On the supposition of moderate or small glacial erosion, a well-

matured stage of dissection must have been attained in the district of the Italian lakes in preglacial time; for the main valleys are widely opened, and even the lateral valleys have flaring slopes. In a mature stage of dissection mountains should exhibit a well-advanced grading of their slopes; that is, their sides should be worn back to a comparatively even declivity with little regard to diversity of structure; the descending streams of waste being thus seen to correspond to the flood plains of graded rivers. The agencies of weathering and transportation are delicately balanced wherever graded slopes prevail; and a slight tilting of the mountain mass might suffice to disturb the adjustment between the supply and the removal of waste; then all the steepened slopes would soon be more or less completely stripped of their waste cover; their rock ledges would be laid bare, although still preserving the comparatively even declivity that had been gained under the slowly moving waste.

If the lakes had been formed by warping, it is possible to deduce with considerable accuracy the localities where the mountain slopes would be steepened and stripped; namely, the northern slopes about the southern end of the lakes, and the southern slopes about the northern end; but as far as I was able to examine the district about Lake Lugano, no effects of such a warping and tilting were to be detected. The submergence of lateral valleys about the middle of the lakes is also, as has been well pointed out by Wallace, a necessary consequence of the theory of warping; but although the main valley floor is now deep under water, the side valleys are not submerged. Failing to find evidence of warping, and being much impressed with the evidence of deep glacial erosion as indicated by the hanging lateral valleys of the overdeepened Ticino, I examined the irregular troughs of Lake Lugano for similar features, and found them in abundance.

One of the reasons why Lake Lugano had been selected for special study was that it did not lie on the line of any master valley leading from the central Alps to the piedmont plains; hence, if influenced by ice action at all, its basin must have been less eroded than those of Como and Maggiore on the east and west. But in spite of this peculiarity of position, Lugano received strong ice streams from the great glaciers of the Como and Maggiore troughs (see Glacial Distributaries, below), and its enclosing slopes possess every sign of having been strongly scoured by ice action. The sides of the lake trough are often steep and cliff-like for hun-

dreds of feet above present water level, thus simulating the basal cliffs of the Ticino valley; while at greater heights the valley sides lean back in relatively well-graded slopes, as in Plate 1, Figure *B*, where the southern side of the northeastern arm of the lake, near Porlezza, is shown. The angle at the change of slope is often well defined, but it is independent of rock structure. Narrow ravines are frequently incised in the basal cliffs, and alluvial fans of greater or less size are built into the lake waters from the base of the ravines.

The northeastern arm of the lake, extending from the town of Lugano to Porlezza, receives several cascading streams from hanging valleys on its southern side, one of which is here shown in Plate 2, Figure *A*. The side slopes of the hanging valleys are for the most part flaring open and well graded, from which it must be concluded that their streams had, under some condition no longer existing, ceased to deepen their valleys for a time long enough to allow the valley sides to assume a mature expression; and that since then the bottom trough of the main arm of the lake has been eroded deep and wide, with a very small accompanying change in the lateral valleys. In other words, the side valleys were, in preglacial time, eroded to a depth accordant with the floor of the master valley that they joined, and since then the bottom trough has been eroded in the floor of the master valley by a branch of the Como glacier. In postglacial time the side streams have begun to trench their valley floors, eroding little canyons; but much of this sort of work must be done before the side valleys are graded down even to the level of the lake waters, much less to the level of the bottom of the lake.

The two southern arms of the lake lead to troughs whose floors ascend southward to the moraines of the foot-hills, beyond which stretch forward the abundant overwashed gravels of the great plain of the Po.

I do not mean to imply that every detail of form about Lake Lugano can find ready explanation by the mature glacial modification of a mature preglacial valley system; but a great number of forms may be thus explained, and a belief in strong glacial erosion was forced upon me here as well as in the valley of the Ticino. A detailed study of the Italian lakes with the intention of carefully sorting out all the glacial modifications of preglacial forms would be most profitable.

Various Examples of Glaciated Valleys.—My excursions of last summer showed me a number of over-deepened main valleys and hanging lateral valleys in the Alps; for example, those of the

Inn and of the Aar. Lakes Thun and Brienz receive numerous cascades from hanging valleys that stand high above the water surface. The valley of Lauterbrunnen also affords a conspicuous illustration of a deep bottom trough enclosed by high basal cliffs that rise to the edge of more open upper slopes; the celebrated Staubbach fall is the descent of a small lateral stream from its lofty hanging valley (see extract from an article by Wallace, cited below), and the picturesque village of Mürren, M, Fig. 5, stands

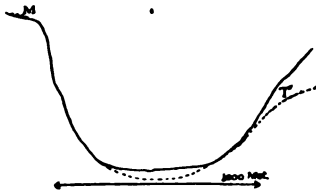


Fig. 5. True-scale cross-section of the Lauterbrunnen valley.

on the flaring slope or *Thalstufe* of the preglacial valley, just above the great basal cliff of glacial origin. A mile or so south of the village of Lauterbrunnen, the Trummelbach, T, Fig. 5, descends the precipitous eastern wall from a hanging valley whose floor is hundreds of feet above that of the Lütschine; it is roughly sketched in Fig. 6. Although the lateral Trummelbach brings a large volume of water to the main valley, it descends by a very narrow cleft in the rock face, a trifling incision in the valley wall; while the main valley, whose trunk stream did not seem to be more than five times the volume of its branch, is half a mile or more broad, wide open and flat-floored. The cross-section of the main valley is over a thousand times as large as that of the lateral cleft. Such a disproportion of main valley and lateral cleft is entirely beyond explanation by the inequality of their streams; and for those who feel that they must reject glacial erosion as the cause of the disproportion, there seems to be no refuge but in ascribing the main valley to recent down-faulting: a process that can hardly be called on to follow systematically along the floors of the larger glaciated valleys of the Alps, and to avoid the non-glaciated valleys and the mountain ridges.

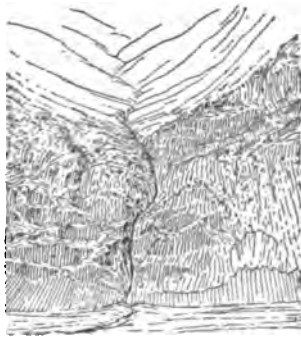


Fig. 6. Diagram of the gorge of the Trummelbach, Lauterbrunnen valley.

Certain well-known Alpine glaciers may be instanced as reaching just beyond the end of a hanging lateral valley and thence cascading into the deeper main valley. One is the Mer de Glace by Chamounix; its cascading end is known as the Glacier des Bois. Another is the neighboring Glacier des Bossons, from whose upper amphitheatre a steep tongue descends far below; like the waterfalls of Norway, the tongue may be seen lying on the side slope from a considerable distance up or down the main valley. A third example is the Glacier of the Rhone, whose splendid terminal cascade is so conspicuous from the road to the Furka pass. (These three I have seen some years ago.) Possibly the Vernagt glacier is another of the same kind; its catastrophic overflows into the lower Rofen valley have often been described. Doubtless many other examples of this class might be named.

While engaged upon these observations in the Alps in the spring of 1899, I sent a brief note about them to my esteemed friend, Mr. G. K. Gilbert of Washington, telling him that all the lateral valleys seemed to be "hung up" above the floors of the trunk valleys. His reply was long in coming to Europe, and, on arriving at last, it was dated Sitka, Alaska, where Mr. Gilbert had gone as a member of the Harriman Alaskan Expedition, and where my note had been forwarded. He wrote that, for the fortnight previous to hearing from me, he and his companions had been much impressed with the discordant relations of lateral valleys over the waters of the Alaskan fiords, and he suggested that such laterals should be called "hanging valleys" — a term which I have since then adopted. He fully agreed that hanging valleys presented unanswerable testimony for strong glacial erosion, as will be stated in his forthcoming report on the geology of the Expedition.

After leaving Switzerland, I had a brief view of the lake district in northwest England, before crossing to Norway. The amount of glacial erosion in the radiating valleys of the English lakes has been much discussed, and as usual directly opposite views have been expressed. Rugged rocky knobs were seen in abundance about Ambleside and along the ridge separating the valley of Thirlmere from St. John's Vale; and the latter receives a hanging valley from the east near Dalehead post-office. The famous falls of Lodore seemed to descend from the mouth of a hanging valley into Derwentwater. A model of the lake district, on exhibition at Keswick, showed some other examples of lateral valleys that seemed to stand above the floors of their main valleys, notably one

coming from the south near the northeast end of Ulleswater. Since coming home I read the following in Marr's "Scientific Study of Scenery":—"We find in the Lake District a number of tributary valleys occurring in the hearts of the ridges, and opening out far above the bottoms of the main valleys, discharging their waters down the slopes in cascades. They are specially well marked on the east side of Helvellyn, and a number of them also open into the upper branches of Borrowdale." The explanation is that of Rüttemeyer and Heim:—"For a considerable period after the deepening of the main valley, the minor valleys will end as definite gorges some height above the floor of the main valley, and discharge their waters in a series of cascades or falls down the side of the main valley" (1900, 136).

One of my former students, Mr. W. B. Lloyd, has recently shown me a number of photographs of the fiords of southern New Zealand, which he brought back from a visit to that distant country. High cascades, plunging from hanging lateral valleys into the broad waters of the fiords, are repeatedly shown; the most striking view is here reproduced in Plate 2, Figure *B* showing Sterling Fall leaping into Milford Sound.

Fiords and Hanging Valleys in Norway.—In Norway I had the pleasure of making a ten days' cross-country excursion in company with Dr. Reusch, Director of the Norwegian Geological Survey. We entered from Bergen through Hardanger fiord, and crossed the highlands by the Haukelisaetr road to Skien on the southeastern lowlands, thus making a general cross-section on which many characteristic features were seen. Norway has long been known as a land of waterfalls, but it is not generally stated with sufficient clearness or emphasis that many or most of the falls are formed by the descent of streams from maturely opened trough-like hanging valleys which are abruptly cut off by the walls of the fiords. The discordance between main and side streams is simply amazing. The fiord valleys are frequently one or two miles wide; the waters of the fiords are of great depths, reaching 3000 feet in some cases. Even when a side valley stands but little above sea-level, its floor may be half a mile above the floor of the fiord. On passing inland beyond the head of the fiord water, where the whole depth of the fiord valley is visible, the side valleys may open more than a thousand feet above the main valley floor. In many cases where the fiords are enclosed by smooth walls, the cascading side streams have not yet incised a cleft in the bare rock surface, so that their foaming

waters are visible for many miles up and down the fiord. Streams of considerable size sometimes plunge down from the rolling uplands in whose edge they seem to have just begun to cut a cleft. Abnormal discordance of trunk and branch stream is, therefore, a strongly marked characteristic of the Norwegian drainage. The necessity for appealing to strong glacial erosion in explanation of this prevailing discordance, may be set forth as follows.

Measure of Glacial Erosion in Norwegian Fiords. — The deep valleys of Norway, partly occupied by sea water, are incised beneath an uneven highland which bears so many hills and mountains that it makes little approach to a peneplain, yet which here and there shows so many broadly opened uplands between the hills and mountains that it may be taken to represent the well-advanced work of a former cycle of denudation when the region stood much lower than it stands now. As a whole, a mature or late mature stage seems to have been reached before a movement of uplift introduced the present cycle. Let us now make two suppositions regarding the work of normal river erosion in the preglacial part of the present cycle, in order to determine, if possible, how much additional erosion must be attributed to ice in the production of existing forms.

First, let it be supposed that the revived main rivers had incised their valleys to the depth of the present fiords in preglacial time, and that the discordance of main and side valleys now visible is the appropriate result of the youth of the present cycle. If we recall only the steepness of the fiord walls, this supposition might be justified, and thus the amount of glacial erosion needed to develop existing forms would be small. But it must not be forgotten that the fiords, although often steep-walled, are always broad, much broader than a young preglacial valley could have been at that stage of early youth when its side streams had not cut down to its own depth. Hence glacial erosion must, under this supposition, be appealed to for the widening of preglacial canyons, steep-walled and narrow, into the existing fiord troughs, steep-walled and broad. At the middle of the fiord troughs, the lateral erosion thus demanded would often measure thousands of feet, and that in the most massive and resistant crystalline rocks.

A second supposition leads to no greater economy of glacial action. Let it be supposed that the revived streams of preglacial time had reached maturity before the advent of the glacial period. In that case, the side streams must have entered the main streams

at accordant grade, and hence the main valleys could not then have been cut much deeper than the side valleys are now cut; not so deep, indeed, for the side valleys have been somewhat deepened by glacial action, if one may judge by their trough-like form as well as by the evidence of intense glacial action all over the uplands, even over most of the surmounting hills and mountains. Hence, to develop the existing discordant valley system from a mature pre-glacial valley system of normal river erosion, requires a great deepening of the fiords by ice action, again to be measured in thousands of feet. Thus there seems to be no escape from the conclusion that glacial erosion has profoundly modified Norwegian topography. As far as I could judge from my brief excursion over the highlands, either one of the two suppositions above considered is permissible, provided only that strong glacial erosion comes after the river work of the current cycle.

If the Hardanger fiord may be taken as the type of its many fellows, one may say that hanging lateral valleys are the rule, not the exception, in Norway. Furthermore, the smoothed, spurless walls of the larger fiords, composed of firm bare rock from the upland to water edge, do not resemble the ravined and buttressed sides of normal valleys. The marks of downward water erosion are replaced by what seem to be marks of nearly horizontal plucking and scouring. Blunt-headed valleys and corries (*botner*) both seem beyond production by normal weathering and washing. Yet, striking as these features are, they do not seem to me so compulsory of a belief in strong glacial erosion as the hanging valleys that have so little relation to the fiords beneath them, and the flaunting waterfalls that descend so visibly from the hanging valleys, instead of retiring, as is the habit of falls all over the unglaciated parts of the world, into ravines where they are hid to sight from most points of view.

The rocky islands that rise from the shallower parts of the fiords should not be taken as signs of feeble glacial erosion, but rather as remnants surviving from the destruction of larger masses in virtue of some slight excess of resistance. A well-known example of this kind is near Odde at the head of the large southern arm (Sørfjord) of the upper Hardanger fiord; but in the same neighborhood are several fine hanging valleys, one of which is shown in Plate 3, Figure 4, its open floor is high above the fiord level; its cascading stream, the Strandfos, descends into Sandven Lake, just south of the side valley occupied by the well-known Buer glacier.

Correlation of River Valleys and Glacier Valleys.— Thus far the consequences of glacial erosion have been described as if they were unlike those of river erosion, especially in respect to the production of hanging valleys. A just comparison of the two agencies will show that their resemblances are more marked than their differences, when due allowance is made for their individual peculiarities.

The likeness of glaciers and rivers has been frequently considered. The motion of water streams and ice streams is retarded by bottom and banks, and is fastest in mid-channel where farthest removed from all hindrances. The motion is faster on strong than on gentle slopes, and in large than in small streams; the line of fastest motion departs from the medial axis towards the concave bank. Forel ('97, 204) and Gannett ('98, 422) have justly compared ordinary valley glaciers, not to rivers that mouth in the sea, but to rivers that descend from mountains to wither away on piedmont deserts. The terminal moraine of the glacier corresponds to the terminal delta-like fan of withering rivers. The fluctuation of a withering river following changes of weather or season corresponds to the secular fluctuations of glaciers, as during the period of about thirty-five years in the Alps. The advance and retreat at the end of large glaciers does not occur synchronously with the advance and retreat of small glaciers, although both large and small glaciers accomplish their periodic variations of length in the same interval; and it is probable that the same contrast obtains in withering rivers of different length, although I cannot find any direct statements to this effect. Meunier ('97, 1043) has suggested that certain peculiar successions of drift deposits in Switzerland may be the result of the enlargement of the drift-bringing glacier by the capture of the head reservoirs of another glacier, after the analogy of rivers. Gannett and Penck (see abstracts below) have gone further still and have shown that the hanging valleys, so characteristic of strongly glaciated drainage systems, have a perfect analogy in the valley systems of ordinary rivers in non-glaciated areas. This comparison is so instructive that it deserves full statement here.

The "nice adjustment of declivities" that characterizes the main and the side valleys of a river system is found only in maturely developed valleys. The adjustment or accordance between main trunk and lateral branch obtains only with respect to the surface of the streams or to the floor of their valleys. The *beds* of the trunk

and the branch channels may be discordant at their junction, and this discordance will increase with the difference in volume of trunk and branch stream. Truly, the discordance of stream beds is seldom noted, because the beds are hidden by the streams; but if a river system were laid dry, we may be assured that the beds of the smaller tributaries would open in the banks of the main river a number of feet from its bottom. In the case of the Mississippi, the discordance might easily measure fifty or more feet.

All this applies equally to glacial streams. The surface of a tributary glacier is adjusted to the surface of the trunk glacier that it joins; but the depth of the beds may be very different. As long as the glaciers occupy their channels, the discordance of their beds may not be often considered, but when a climatic change causes the glaciers to melt away, their channels are called "valleys," and the discordance of main and lateral glaciated "valley floors" is taken as an abnormal feature. In reality the discordance is perfectly normal to the peculiar system of ice drainage by which it was produced, however discordant it may be to the system of water drainage now in possession of the valleys. Let us compare the maturely developed channels of rivers and glaciers.

Channels of Mature Rivers and Glaciers.—A river flows rapidly; and the cross-section of its channel is but a small fraction of the cross-section of its valley. The river channel is U-shaped, very broad compared to its depth, while the valley sides flare open, V-like, above the river banks. The water surface slopes steadily down-stream, but the channel bed has many small inequalities in the form of bars and basins, and the water in the bottom of the basins must ascend a little to get out of them. If the river should dry away, the deeper parts of the bed would be occupied by pools of standing water, while the bars would show lines suggestive of flowing water. The banks of the river channel are smoothly worn in nearly horizontal lines, parallel to the flow of the river current, while the sloping sides of a river valley are buttressed with spurs and scored by the down-hill ravines of descending streams. At the junction of trunk and branch streams, a moderate discordance in the level of the channel beds is to be expected; but this is seldom considered, because the channels are usually occupied by water and the beds are hidden.

A glacier moves slowly, and the cross-section of its channel may be a considerable part of the cross-section of the valley that it drains. Forel estimates that the glacier of the Rhone, even where

descending its steep cascade, has only 1 : 12,000,000 of the velocity of a large river on a similar slope ('97, 203). The glacial channel is U-shaped, broad and deep, while the valley flares open, V-like, above the ice surface. The ice surface slopes steadily down-stream, but the bed of its channel is unevenly scoured, here rising in knobs, there sinking in hollows or basins from which the bottom ice must ascend a little as it moves forward. When the ice melts away, lakes occupy the rock basins; the rocky knobs are seen to be rounded and plucked in a manner suggestive of heavily moving ice. The banks of the channel are scoured and fluted parallel to the ice motion; but above the ice-worn channel the flaring valley sides are rayined by descending water streams. At the junction of trunk and branch glaciers a strong discordance in the level of the channel beds may be expected; and the discordance becomes conspicuous when the glaciers melt away and leave their "channels" to be called "valleys." Hanging side valleys are therefore appropriate as well as characteristic features of glaciated main valleys. They must come to be considered even more significant of glacial erosion than lake basins.

The Cycle of Glacial Denudation. — The points of resemblance between rivers and glaciers, streams of water and streams of ice, are so numerous that they may be reasonably extended all through a cycle of denudation. Let us then inquire if glaciers may not, during their ideal life history, develop as orderly a succession of features as that which so well characterizes the normal development of rivers. The "life history of a glacier" need not be taken only in the sense so well illustrated in the last chapter of Russell's "Glaciers of North America," where the glacier is called young when it is small at the beginning of a glacial climatic epoch; mature when it is largest during the full establishment of the glacial climate; and old when it is vanishing under the re-establishment of a milder climate. Let us here consider the life history of a glacier under a constant glacial climate, from the beginning to the end of a cycle of denudation, just as Russell has considered the "life history of a river" under a constant pluvial climate, in his "Rivers of North America." Thus young glaciers will be those which have been just established in courses that are consequent upon the slopes of a newly uplifted land surface; mature glaciers will be those which have eroded their valleys to grade and thus dissected the uplifted surface; and old glaciers will be those which cloak the whole lowland to which the upland has been reduced, or which are slowly

fading in the milder climate of the low levels appropriate to the close of the cycle of denudation.

Imagine an initial land surface raised to a height of several thousand feet, with a moderate variety of relief due to deformation. Let the snow line stand at a height of two hundred feet. As elevation progresses, snow accumulates on all the upland and highland surfaces. Glaciers are developed in every basin and trough; they creep slowly forward to lower ground, where they enter a milder climate (or the sea) and gradually melt away. At some point between its upper heads and its lower end, each glacier will have a maximum volume. Down stream from this point, the glacier will diminish in size, partly by evaporation but more by melting; and the ice water thus provided will flow away from the end of the glacier in the form of an ordinary stream, carving its valley in normal fashion. Some erosion may be accomplished under the upper fields of snow and *névé*, but it is believed that more destructive work is done beneath the ice. The erosion is accomplished by weathering, scouring, plucking and corradng. Weathering occurs where variations of external temperature penetrate to the bed-rock, as is particularly the case between the *séracs* of glacial cascades, and again along the line of deep crevasses or *bergschrunds* that are usually formed around the base of reservoir walls, which are thus transformed into *corries* (*cirques*, *karen*, *botner*) as has been suggested by several observers; scouring is the work of rock waste dragged along beneath the glacier, by which the bed-rock is ground down, striated and smoothed; plucking results from friction under long-lasting heavy pressure, by which blocks of rock are removed bodily from the glacier bed and banks; corradng is the work of subglacial streams, which must be well charged with tools, large and small, and which must often flow under heavy pressure and with great energy. All these processes are here taken together as "glacial erosion."

Let it be assumed that at first the slope of a glacier's path was steep enough to cause it to erode for the greater part or for the whole of its length. Each young glacier will then proceed to cut down its consequent valley¹ at a rate dependent on various factors, such as depth and velocity of ice stream, character of rock bed, quantity of ice-dragged waste, and so on; and the eroded

¹ A valley is understood to include the channel that is eroded along its floor. The channel, with its bed and banks, is therefore that part of a valley which is occupied by the stream.

channel in the bottom of the valley will in time be given a depth and width that will better suit the needs of ice discharge than did the initial basin or trough of the uplifted surface. The upper slopes of the glacial stream will thus be steepened, while its lower course will be given a gentler descent. Owing to the diminution of the glacier toward its lower end, the channel occupied by it will diminish in depth and breadth downwards from the point of maximum volume; this being analogous to the decrease in the size of the channel of a withering river below the point of its maximum volume. A time will come when all the energy of the glacier on its gentler slope will be fully taxed in moving forward the waste that has been brought down from the steeper slopes; then the glacier becomes only a transporting agent, not an eroding agent, in its lower course. This condition will be first reached near the lower end, and slowly propagated headwards. Every part of the glacier in which the balance between ability to do work and work to be done is thus struck may be said to be "graded"; and in all such parts, the surface of the glacier will have a smoothly descending slope. Maturity will be reached when, as in the analogous case of a river, the nice adjustment between ability and work is extended to all parts of a glacial system. In the process of developing this adjustment, a large trunk glacier might entrench the main valley more rapidly than one of the smaller branches could entrench its side valley; then for a time the branch would join the trunk in an ice-rapid of many séracs. But when the trunk glacier had deepened its valley so far that further deepening became slow, the branch glacier would have opportunity to erode its side valley to an appropriate depth, and thus to develop an accordant junction of trunk and branch ice *surfaces*, although the *channels* of the larger and the smaller streams might still be of very unequal depth, and the channel *beds* might stand at discordant levels. If the glaciers should disappear at this stage of the cycle, their channels would be called valleys, and the discordance of the channel beds might naturally excite surprise. The few observers who, previous to 1898, commented upon a discordance of this kind, explained it as a result of excessive erosion of the main valley by the trunk glacier; while the hanging lateral valleys were implicitly, if not explicitly, regarded as hardly changed from their preglacial form.

When the trunk and branch glaciers have developed well-defined, maturely graded valleys, the continuous snow mantle that covered the initial uplands of early youth is exchanged for a discontinuous

cover, rent on the steep valley sides where weathering comes to have a greatly increased value, and thickened where the ice streams have established their courses. This change corresponds to that between the ill-defined initial drainage in the early youth, and the well-defined drainage in the maturity, of the river cycle.

It is probable that variations in rock structure will have permitted a more rapid development of the graded condition in one part of the glacial valley than in another, as is the case with rivers of water. Steady-flowing reaches and broken rapids will thus be produced in the ice stream during its youth; and the glacial channel may then be described as "broken-bedded." But all the rapids must be worn down and all the reaches must become confluent in maturity. It is eminently possible that the reaches on the weaker or more jointed rocks may be eroded during youth to a somewhat greater depth than the sill of more resistant or less jointed rock next down stream; and if the glacier should vanish by climatic change while in this condition, a lake would occupy the deepened reach, while the lake outlet would flow forward over rocky ledges to the next lower reach or lake. Many Norwegian valleys today seem to be in this condition. Indeed some observers have described broken-bedded valleys as the normal product of glacial erosion, without reference to the early stage in the glacial cycle of which broken-bedded glacial channels seem to be characteristic. Truly, it is not always explicitly stated that the resistance of the rock bed varies appropriately to the change of form in a broken-bedded channel; but the variations of structural resistance or firmness that the searching pressure and friction of a heavy glacier could detect might be hardly recognizable to our superficial observations; and on the other hand the analogy of young ungraded glaciers with young ungraded rivers seems so natural and reasonable that broken-bedded glacial channels ought to be regarded only as features of young glacial action, not as persistent features always to be associated with glacial erosion. If the glaciers had endured longer in channels of this kind, the "rapids" and other inequalities by which the bed may be interrupted must have been worn back and lowered, and in time destroyed.

If a young glacier erodes its valley across rocks of distinctly different resistances, a strong inequality of channel bed may be developed. Basins of a considerable depth may be excavated in the weaker strata, while the harder rocks are less eroded and cross the valleys in rugged sills. Forms of this kind are known in Alpine valleys; for example, in the valley of the Aar above Meiringen

(Wallace, '96, 176) and in the lower Gasterthal near its junction with the Kanderthal; in both these cases the basins have been aggraded and the sills have been trenched by the postglacial streams. In the lower Gasterthal the height and steepness of the rocky sill, when approached from up-stream, is astonishing; its contrast to the basin that it encloses is difficult enough to explain even for those who are willing to accept strong glacial erosion. It should, however, be noted that river channels also are deeper in the weaker rocks up-stream from a hard rock sill; if the river volume should greatly decrease, a small lake would remain above the sill, drained by a slender stream cutting a gorge through the sill.

If an initial depression occurred on the path of the glacier, so deep that the motion of the ice through it was much retarded, an ice-lake would gather in it. Then the waste dragged into the basin from up-stream might accumulate upon its floor until the depth of the basin was sufficiently decreased and the velocity of the ice through it sufficiently increased to bring about a balance between ability to do work and work to be done. Here the maturely graded condition of the ice stream would have been attained by aggrading its bed, instead of degrading it; this being again closely analogous to the case of a river, which aggrades initial depressions and degrades initial elevations in producing its maturely graded course.

Water streams subdivide toward the headwaters into a great number of very fine rills, each of which may retrogressively cut its own ravine in a steep surface, not cloaked by waste. But the branches of a glacial drainage system are much more clumsy, and the channels that they cut back into the upland or mountain mass are round-headed or amphitheatre-like; but the beds of the branching glaciers cannot be cut as deep as the bed of the large glacial channel into which they flow: thus corries, perched on the side-walls of large valleys, may be produced in increasing number and strength as glacial maturity approaches, and in decreasing strength and number as maturity passes into old age. As maturity approaches, the glacial system will include not only those branches that are consequent upon the initial form, but certain others which have come into existence by the headward erosion of their *névé* reservoirs following the guidance of weak structures; thus a maturely developed glacial drainage system may have its subsequent as well as its consequent branches. It is entirely conceivable, as has been suggested by Meunier, that one ice stream may capture the upper part of another. The conditions most favorable for such a

process resemble those under which river diversions and adjustments take place; namely, a considerable initial altitude of the region, allowing a deep dissection; a significant difference of drainage areas or of slopes, whereby certain glaciers incise deeper valleys than others; a considerable diversity of mountain structure, permitting such growth and arrangement of subsequent glaciers as shall bring the head reservoir of a subsequent ice stream alongside of and somewhat beneath the banks of a consequent ice stream. Thus glacial systems may come to adjust their streams to the structures upon which they work, just as happens in river systems.

The load transported by a glacial system may at first be supplied largely by waste plucked and scoured from the beds of the glacial channels as well as by waste detached from the enclosing slopes; but in time, when the graded condition of the chief channels is reached and their further deepening almost ceases, by far the largest share of load will be supplied from the subaerial valley sides, where weathering of the ordinary kind will ravine the slopes, thus producing a topography that is strongly contrasted with the smooth walls of the glacial channels. If the initial glacial system should incise its channels so deeply beneath a lofty highland that the supply of waste from the valley sides continued to increase after the development of graded glacial channels, it is conceivable that the channel-beds might have to be aggraded for a time, as is believed to be the case with river channels under similar conditions; but owing to the receipt on the glacial surface of waste from the valley sides, it is also conceivable that this analogy may not closely obtain. Toward the end of the ice stream it may well happen that the diminution of its volume and the consequent diminution of its capacity to do work will result in the aggradation of its bed by waste that cannot be carried further forward. At the same time, the outflowing river may be unable to wash away all the waste that is delivered to it, and so, for a time through later youth and early maturity, the river may act as an aggrading agent and build up a broad, flat alluvial fan, such as fronts the terminal moraines of the Alpine glaciers that once descended to the plain of Lombardy. Some response to the change thus produced in the altitude of the end of the glacier may be expected far up its channel, whose bed would thus come to be aggraded with till. Similarly, the ice sheets that spread from the Scandinavian and Laurentian highlands over the lowlands on the south changed their behavior from degrading agents in the central area to aggrading agents on the peripheral area. Hence, a belief in

effective erosion is not antagonistic to a belief in effective deposition in the case of glaciers any more than in the case of rivers. In each case the action varies appropriately to its place in the drainage system and to its stage in the cycle. But there will be a later stage, when the wasting of the superglacial slopes reduces them to moderate declivity, so that the waste delivered from them decreases in quantity; then the outflowing water stream at the end of the glacier may become a degrading agent; the altitude of the end of the glacier may be slowly lessened; and a very slow and long-continued deepening of the whole glacial channel will take place, without requiring a departure from an essentially graded condition.

As the general denudation of the region progresses, the snow fall must be decreased and the glacial system must shrink somewhat, leaving a greater area of lowland surface to ordinary river drainage. When the upland surface is so far destroyed that even the hill tops stand below the 200-foot contour, the snow fields will be represented only by the winter snow sheet, and the glaciers will have disappeared, leaving normal agencies to complete the work of denudation that they have so well begun.

If a snow line at sea-level be assumed, glaciation would persist even after the land had been worn to a submarine plain of denudation at an undetermined depth beneath sea-level. The South Polar regions offer a suitable field for the occurrence of such a surface.

Whether glaciers of the Norwegian or of the Alpine type shall occur, is dependent partly on initial conditions, partly on the stage of advance through the cycle of denudation. If the initial form offer broad uplands, separated by deep valleys, snow fields of the Norwegian type may have possession of the uplands during the youth of the glacial cycle; but when maturity is reached, the uplands will be dissected, and the original confluent snow field will be resolved into a number of head reservoirs, separated by ridges. On the other hand, as the later stages of the cycle are approached, the barriers between adjacent reservoirs will be worn away, and they will tend to become confluent, here and there broken only by Nunatuker. If the snow line lay low enough, a completely confluent ice and snow shield would cover the lowland of glacial denudation when old age had been reached. If the glacial conditions of Greenland preceded as long as they have followed the glacial period over the rest of the North Atlantic region, who can say how far the ice of the Greenland shield has modified the forms on which its work began!

Glacial Distributaries. — If a maturely dissected mountain range were occupied by snow-fields and glaciers of large size, certain peculiar results might be expected near the mountain base. Under normal preglacial conditions, a small low ridge suffices for the complete separation of two river systems, because the channels of rivers are so small in comparison to their valleys. But glacial channels are a large part of their valleys, and when great glaciers from the lofty mountain centres descend by the master valleys to the mountain flanks or even to the piedmont plains, distributary ice streams or outflowing branches may naturally enough be given off wherever the ice surface rises high enough to overtop the ridges by which the master valleys are separated from adjacent minor valleys. If a distributary branch has sufficient strength and endurance, it may wear down the ridge that it crosses and thus increase and perpetuate its lateral discharge; but it cannot usually be expected to erode a channel as deep as that of the main glacier from which it departs. On the disappearance of the ice, a hanging valley will be left above the floor of the master valley; but in this case, the drainage of the hanging valley will be away from, not toward, the master. Here we probably have the explanation of those broad hanging valleys which lead from the valley of Lake Maggiore on the west and, less distinctly, from that of Lake Como on the east to the compound basin of the intermediate Lake Lugano. On going southward by rail from Bellinzona to Lugano, along a stretch of the St. Gotthard route between the great tunnel and Milan, the railway obliquely ascends the southeastern wall of the trough-like valley of the Ticino just above the head of Lake Maggiore; and at a height of several hundred feet over the delta flood-plain the line turns off to a well-marked hanging valley in which the stream runs away from the Ticino to Lake Lugano. The notch made by this supposed glacial distributary is a conspicuous feature in the view from Bellinzona and thereabouts.

The anomalous forking of Lake Como and the open branch from the main valley of the Rhine at Sargans through the trough of Wallen See to Lake Zurich appear to be the paths of large glacial distributaries which eroded their channels deeply across divides that presumably existed in preglacial time. The west wall of the main valley of the Isère in the Alps of Dauphiny, southeastern France, is deeply breached by passes that lead northwest to the troughs of Lakes Annecy and Bourget, through which the distributaries of the Isère glacial system must have flowed. Lugéon ('97, 62-70) has

explained the breaches as marking the former northwest paths of transverse members of the Isère system, from which they have been diverted by the subsequent growth of the main longitudinal valley — that northeast-southwest part known as the Grésivaudan — above Grenoble. His discussion of the problem takes, however, no account of modifications of valley depth by glacial erosion; and as this must have been considerable (for the valleys hereabouts have superb basal cliffs, as appears in the valley of the Romanche by Bourg d'Oisans in Plate 3, Fig. *B*, after a photograph by Neurdin Frères of Paris), it may well be that the rearrangement of river courses in this interesting region is not altogether the work of river action. Similarly, the various modifications of the Rhine system in eastern Switzerland, explained by Heim as the work of streams alone, may come to be at least in part referred to ice erosion.

It may be further supposed that if the preglacial valleys were so arranged that a glacial distributary found a shorter and steeper course to the piedmont plain or to the sea than that followed by the master glacier, the distributary might under a long enduring glaciation become the main line of glacial discharge; and if so, it could be eroded to a greater depth than the former master valley at the point of divergence. In such a case, the postglacial river drainage would differ significantly from the preglacial. There is reason for believing that examples of this kind are to be found in Norway, the evidence of which will soon be published in an essay by Barrett (1900). The diversion of the head of a stream in the Sierra Costa of northwestern California to a deeper-lying valley through a gorge cut by a glacial distributary has lately been described by Hershey (1900, 47).

The Depth of Mature Glacial Channels.—The depth with respect to sea-level to which the channels of a glacial system may be eroded when the graded condition is reached, is a subject of special interest. For many miles along the lower course of a branchless trunk glacier, its volume is lessened by melting and evaporation, and at its end the ice volume is reduced to zero; slow ice motion being progressively replaced by rapid water motion. In such a case the law of continuity does not demand that the ice velocity shall be inversely proportional to the area of the cross section, as is the case in the normal river (where it is assumed that there is no loss by evaporation). Indeed, in the lower trunk of a mature glacier, it may well be that the velocity of ice movement is in a rough way directly proportional to cross-section area. This appears to be veri-

fied by measurements of the Rhone glacier, where the mean annual movement is 110 met. in the heavy trunk above the cascade, 27 met. just below the cascade, and only 5 met. close to the melting front (Forel, '97, 203). Evidently then, the erosion of the glacial bed, in so far as it is determined by the pressure and motion of the ice stream, will have its maximum some distance up-stream from the end of the glacier (J. Geikie, '98, 236). The glacial channel must therefore become narrower and shallower as its end is neared, as has already been stated. If the glacier ends some distance inland from the sea, its action will be conditioned by the grade and length of the river that carries away the water and waste from its lower end. The deepening of the distal part of the channel accomplished in youth might be followed by a shallowing for a time during maturity, when the accumulation of morainal and washed materials in front of the glacier compelled its end to rise. Now it may well be conceived that the surface slope of such a glacier near its end is less than the angle between the surface and the bottom of the glacier; and in this case, the glacial floor must become lower and lower for a certain distance up-stream. If such a glacier should melt away, the distal part of its channel would be occupied by a lake, although even the head of the lake may not reach to the locus of maximum glacial erosion. Lakes Maggiore, Como and Garda seem to occupy basins whose distal enclosure by heavy moraines and sheets of over-washed gravels has added to the depth produced by erosion further up-stream. It would seem, however, that a lake basin thus situated must be only a subordinate incident in the general erosion of the whole length of the glacial channel. Too much attention has, as a rule, been given to lakes of this kind, and not enough to the other effects of glacial action; it seems especially out of proportion to suppose that the maximum erosion by a glacier takes place near its end, as has been done by some authors, on account of the prevalent occurrence of lakes in this situation.

If a glacier advances into the sea and ends in an ice cliff, from which ice blocks break off and float away, something of a basin-like form of its lower channel may be produced; but the dimensions of this basin will be determined by the climate at the termination of the glacier. If the climate is such as to allow the glacier to enter the sea in maximum volume, then a basin is not to be expected. The more the glacier diminishes towards its end, the less erosion and the more deposition may occur beneath it, and the more of a basin may be developed inland from its end.

The depth to which a glacier may cut its channel when it enters the sea is of particular importance. If the glacier is a thousand feet thick at its end, it must continue to press upon and scour its bed until only about 140 feet of ice remain above sea-level; its channel will thus be worn more than 800 feet beneath sea-level. Truly, the latter part of this work will be performed with increasing slowness; but if time enough be allowed the work must be accomplished, just as is the case with rivers. If a glacier should melt away from its deep entrenchment, its channel would be occupied by an arm of the sea or fiord, reaching many miles into the land. The fiord might be shallower at its mouth than further inland, if differential erosion and deposition had occurred along its channel. Yet even this result is analogous to the case of a river; for if the Mississippi were to disappear in a prolonged drought, a slender arm of the sea would invade the river channel many miles up-stream from the delta front. Indeed, the Mississippi offers an excellent example of a channel that is basined inward from the river mouth; for while it is only a score of feet deep at the passes where most of its sediment is deposited, it is several score of feet in depth further up-stream; and the slender arm of the sea that would occupy its channel if it should disappear by climatic change, would be truly fiord-like in having a less depth at its mouth than further inland.

An important corollary from this conclusion — perhaps not so much of a novelty to glacial erosionists as to their confreres of the opposite opinion — is that the depth of water in the fiords of a strongly glaciated coast is not a safe guide to the movement of the land since preglacial time. If there had been a still-stand of the earth's crust through the whole glacial period, the preglacial river channels that were graded down a little below sea-level at their mouths would be replaced by glacial channels that might be eroded hundreds of feet below sea-level. The depth of fiords thus seems to depend on the size of their ancient glaciers, on the height of the mountain background, and on the duration of the glacial period, as well as on movements of the land. If liberal measures of glacial erosion and glacial time are allowed, no depression of glaciated coasts since preglacial time is needed to account for their peculiar features. The glacial channels may have been simply invaded by the sea, as the ice melted away, without any true submergence.

Even the advocates of strong glacial erosion do not seem to have explicitly recognized the full importance of this possibility. James Geikie, for example, writes: "The fiords of high latitudes and the

narrow inlets of non-glaciated lands are simply submerged land-valleys; the intricate coast-lines of such regions have been determined by preceding subaerial denudation." Again: "In a word, fiords are merely the drowned valleys of severely glaciated mountain-tracts." ('98, 263, 250.) The deep waters in the valley of the Hudson through the Highlands of southeastern New York are the most fiord-like in the eastern United States, and they are universally explained as the result of submergence of a normal river valley; but the constricted ice current that must have flowed through the Highland gorge may have been energetic enough to deepen its bed beneath sea-level, and since the ice melted away, who can say how much submergence beneath preglacial levels has taken place. I do not know how far this view of the matter has been taken by earlier advocates of strong glacial erosion, but for my own part, the acceptance of such a possibility means a complete reversal of the belief that I held two years ago. The reversal is, however, accompanied by the memory that it was always difficult to understand why submergence and glaciation were so closely associated: even if glaciation had caused depression, it was difficult to understand why the relief from ice pressure in postglacial time had not now been followed by a rise of the land much nearer to its former altitude than would be the case if the greater part of the depth of fiords is explained by submergence.

The Origin of Corrie Basins. — On pursuing the above line of consideration a little further, it may give some light on the occurrence of the small rock basins that are so often found in the floor of cliff-walled corries. Imagine that a large glacial system has become maturely established, and that it "rises" in many blunt head-branches that have excavated corries in a preglacial mountain mass, and have cut down channels, at their junction with the larger branches or trunk glacier, to a depth appropriate to their volume. Unless the erosion of the corries has been guided by differences of rock structure, there does not seem to be reason for their possessing a basined floor at this stage of development; but if a change of climate should now cause the trunk glacier to disappear, while many of the blunt head-branches remain in their corries, each little glacier thus isolated will repeat the conditions of erosion above inferred for the trunk glacier; and if this style of glaciation linger long enough, rock basins may very generally characterize the floors of the corries when the ice finally melts away. Figure 7 may make this clearer. Let the broken line, ABC, be the slope of a preglacial lateral ravine

which reaches a trunk stream at C, while ADC is the profile of an adjoining lateral spur. After vigorous and mature glaciation, the dotted line, GE, may represent the surface slope of a lateral glacier, and GHJ that of the lateral glacier bed; while EFL is the surface of the trunk glacier, and EKL the bed. The lower part of the lateral spur has been cut off to make the basal cliff beneath D. On

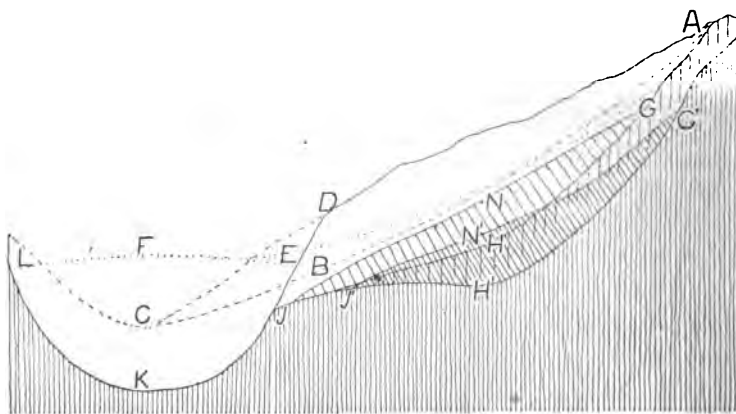


Fig. 7. Diagram-section of a lateral valley with a corrie basin.

the disappearance of the trunk glacier at this stage, the shrunken side glacier, GNJH, occupies its corrie or hanging valley, which opens at J on the oversteepened wall, DJK, of the evacuated channel of the trunk glacier. Let the maximum erosion of the corrie glacier, as conditioned by pressure and motion, be at H. Then after some time the weathering of the cliff walls and the erosion of the floor will have transformed the corrie and its glacier to a form, G'N'J'H', such that the deepening of the glacial bed should be a maximum at HII'. The continuous slope of the glacial bed, GHJ, appropriate to the time when the lateral glacier joined the trunk glacier, may thus be transformed into a basined curve, G'H'J', appropriate to a small glacier terminating at J'; and on the disappearance of the small glacier, a tarn or rock-basin lake may occupy the depression at H'. It is on the basis of a supposition like this that a determination has been attempted of the altitude at which the shrinking remnants of an extensive glacial system endured for a time before their entire disappearance (J. Geikie, '98, 233). Richter's supposition that the uplands of Norway result from the

consumption of pre-existent mountains by the great extension of corrie-glacier floors, each similar to J' H', thus seems mechanically possible; but it is nevertheless climatically very improbable, and it seems to me deficient in not attributing enough work to normal pre-glacial erosion.

Overdeepened Valleys and Oversteepened Walls.—As in the case of the normal cycle of denudation in which the life history of river systems is involved, so in the glacial cycle, all manner of complications may arise, causing great departures from the ideal case. The assumed initial land form may be a surface previously more or less dissected by river erosion, on which glaciers must then proceed to develop a drainage system appropriate to their own peculiar needs, as has been partly considered above in connection with glacial distributaries. It will be instructive to make out a good series of examples illustrating different combinations of river and glacial action, and including young, mature and old river valleys, modified by young or mature glaciation. For example, the existing valley of the Rhue in the Central Plateau of France shows a submature river valley with incised meanders, moderately affected by young and relatively light glaciation; the valley of the Ticino in the southern Alps is a well-matured preglacial river-valley system, modified by strong submature glaciation. The fiords of Norway result from the submature and intense glaciation of a river-valley system whose stage of preglacial development is not yet well determined.

Interruptions of regular progress in the glacial cycle must, as in the river cycle, be occasioned by elevation, depression, or deformation of the land mass; but no examples of complications of this kind can be adduced. Variations of climate may replace creeping glaciers in young, mature or old stages of development, by flowing rivers; and the early stages of such rivers are of much importance among existing geographic forms. Lakes, delaying the river flow, occupy the depressions of the glaciated surface, as has been known since Ramsay first pointed out the correlation of lacustrine and glaciated regions in 1861; but the analogy between lakes in the beds of melted glaciers and pools in the beds of dried-up rivers has perhaps not been sufficiently insisted upon. Waterfalls connect the streams that occupy the discordant beds of glacial channels, as has lately been clearly set forth. Landslides frequently occur after the supporting glacier withdraws from the oversteepened banks of its huge channel; fallen masses of this origin have been repeatedly mistaken for moraines in Alpine valleys, as has been lately shown by Brück-

ner. Every lake or fiord is an effective lowering of base-level for the stream above it; for the level of a body of standing water is essentially the same at both ends. As fast as the inflowing river builds its delta forward at the head of the lake or fiord, its flood plain must rise up-stream and aggrade the valley floor. This process is very pronounced in many Alpine valleys, where the aggraded valley floor has a relatively rapid descent on account of the plentiful and coarse detritus furnished by the active side streams. Indeed, every ravine furnishes a great quantity of rock waste, whose descent is analogous to repeated landslides of small dimensions. The valley floor beneath the ravines is invaded by great alluvial fans, and the main stream is driven away toward the further valley wall by their rapid advance. At every flood, the waste supplied from the fans is swept abundantly into the main stream, whose flood-plain grows rapidly as a delta in the upper end of each lake that it enters. The delta of the Ticino seems to have advanced so far into what was originally the basin of Lake Maggiore that the apparent height of the hanging lateral valleys steadily decreases toward the lake; and for several miles above the head of the lake the lateral valleys seem to enter the main valley almost at grade, although there can be little doubt that if all the delta alluvium were removed, the lateral valleys would be found to stand high above the rock floor of the main valley. The standing lakes, the aggrading flood-plains, and the growing fans all show that the bed of the glacial channel has been worn too deep to serve as a valley floor for the existing river; the river must aggrade, with water or with waste, the bed of the channel that the glacier degraded; hence Penck has suggested that glaciated valleys of the Alpine kind should be called "overdeepened." In the same way, the waterfalls from the hanging valleys, the showering waste that forms the fans, and the landslides from the basal cliffs, all show that the banks of the glacial channel—the lower walls of the existing valleys—are too steep; and they may be therefore called "oversteepened." Much glacial work had to be done upon the mature preglacial valleys of river erosion, to bring them into mature adjustment with the needs of glaciers; much river work must likewise now be done upon the overdeepened glaciated valleys, and upon their oversteepened walls and their hanging branches, before they can be maturely adjusted again to the needs of rivers.

Practical Utility of the Ideal Glacial Cycle.—In every case, the full understanding of the conditions developed by any system of

glaciers, existing or extinct, can be reached only by a complete analysis of the conditions under which they began to work, of the energy with which they worked, of the part of a cycle during which they worked, and of the complications of climatic change or of crustal movements by which their work was modified in this way or in that. A partial analysis may suffice for a particular instance; but the explorer will be better equipped for the explanation of all the instances that he discovers if he sets out with a well-elaborated conception of the ideal glacial cycle of denudation, and of the complications it is likely to suffer. However extensive and definite this conception may be, exploration will probably require its further extension and definition; however brief exploration may be, it will probably be aided by an orderly examination of all pertinent knowledge previously accumulated.

As a practical instance of the value of the glacial cycle, we may consider the aid given toward the solution of certain problems by the careful reconstruction — or at least the conscious attempt at reconstruction — of the form of the land surface on which the pleistocene glaciers began their work, and by the legitimate deduction of the characteristics of maturity in the cycle of glacial erosion. Beyond the mature stage, we may seldom have occasion to go, as there do not seem to be actual examples of more advanced glacial work. The initial form on which pleistocene glacial action began is in no case known to be that implied in the opening paragraphs of the section on the Glacial Cycle; namely, a land mass freshly uplifted from beneath the sea and not previously carved by the streams of an ordinary or normal cycle of erosion. In central France, for example, the initial form was an uplifted and submaturely dissected peneplain, in which valleys with incised meanders had been habitually developed. It was there of the greatest assistance to carry into the glaciated area a clear picture of its preglacial form, as determined by generalizing the adjacent non-glaciated area. At the same time, the ideal picture of a maturely developed glacial drainage system, with smooth-sided troughs, was seen to represent a much more advanced condition than was attained in the rugged valley of the Rhue; and thus a tolerably definite idea was gained of the youthful stage of glacial development, somewhere between its beginning and its maturity, and of the amount of destructive work needed to reach this youthful stage. This elementary example illustrates a method embodying the cycle of glacial denudation that ought to be applied whenever possible.

The larger Norwegian fiords may be instanced as glacial channels that present every appearance of having advanced far toward the mature stage of a cycle of glacial denudation from an initial or preglacial form not yet well understood. The variation of form between the main fiords and their branches gives some indication that the glacial work was accomplished in several successive epochs, with the interglacial epochs of normal river work between; but this is only a suggestion, needing much more field work before it can be assured. Not only the deep fiords, but the hanging valleys and the uplands also, have been ice-scoured; for hanging valleys frequently have a well-defined U-section, and sometimes receive secondary hanging valleys from the enclosing uplands; and the streams of the uplands exhibit repeated departures from the forms of normal erosion. Although possessing little drift, the uplands frequently bear lakes of moderate depth and irregular outline; in spite of the breadth to which the upland valleys are opened between the surrounding hills and mountains, their streams frequently change from wandering at leisure in split or braided channels along broad floors, to dashing down in haste over rocky rapids: a behavior that is manifestly inconsistent with that of the mature drainage of a normally denuded region. Even the surmounting hills exhibit strong scouring on their up-ice-stream side. It does not therefore seem permissible to conclude that the hanging valleys which open on the walls of the greater fiords have not been deepened by ice erosion because they escaped the more severe glaciation that scoured out the fiords themselves. All the valleys have been glaciated, and all have been significantly modified from their preglacial form. The discordance of overdeepened main fiord and hanging lateral valley seems to me best explained as the result of the mature development of glacial drainage, in which the chief trunks and the larger branches of the glacial systems had for the most part reached a graded condition. Trunk and branch glaciers would then have united at even grade as to their upper surface, and the trunk and branch channels would have had dimensions satisfactory to the ice currents which flowed through them, but the channel beds would have been discordant, as they are found to be.

REVIEW OF PREVIOUS WRITINGS ON HANGING VALLEYS.

It has already been stated that hanging side valleys and overdeepened main valleys have not yet been generally given the impor-

tance that they deserve as witnesses to strong glacial erosion. Russell, in his "Glaciers of North America" (1897), makes no mention of discordant lateral and main valleys when discussing glacial erosion. James Geikie, in his "Earth Sculpture" (1898), allows to discordance of glaciated valleys hardly more than a secondary importance in abstracts and quotations from Wallace's accounts of Alpine lakes and from Richter's essay on Norway (see below), while the glacial erosion of lake basins is much more fully treated. Yet of all the facts that point to strong glacial erosion, none seem to give testimony so unanswerable as do hanging valleys. The following extracts will serve to illustrate the gradually increasing recognition of their importance.

Forbes on the Waterfalls of Norway. — Thinking that some interesting early observations on the hanging valleys of Norway might be recorded in Forbes' book of travels in that country, I looked up waterfalls in his index and there found a reference to the cause of their profusion, which was stated as follows.

"The source of this astonishing profusion of waters is to be found in the peculiar disposition of the surface of the country so often referred to. The mountains are wide and flat, the valleys are deep and far apart. . . . As the valleys ramify little . . . and are wholly disconnected from the *fields* [uplands] by precipitous slopes, it follows that the single rivers which water those valleys . . . are supplied principally by streamlets which, having run long courses over the *fields*, are at last precipitated into the ravines in the form of cascades" ('53, 251).

Forbes was an excellent observer, yet this quotation is about equivalent to saying that there are many waterfalls in Norway because there are steep slopes over which the streams of the uplands must descend. The quotation deserves a place here if for nothing more than to show the advance of a half century in regard to what constitutes the cause of a geographical feature.

McGee on Glacial Canyons, 1883. — The earliest article that I have found touching on this subject is the brief abstract of a paper read by McGee before the American Association in 1883, entitled "Glacial Cañons." Observations in the Sierra Nevada led this keen observer to state that "the effect of the *temporary* occupancy of a typical water-cut cañon by glacier ice will be to (1) increase its width, (2) change the original V to a U cross profile, (3) cut off the terminal portions of tributary cañons and thus relatively elevate their embouchures, (4) intensify certain irregularities of gradient in

the cañon-bottom, (5) excavate rock-basins, (6) develop cirques, and, in general, transform such cañon into an equally typical glacial cañon" ('83, 238). A later paper by the same author is referred to below.

Hanging Valleys in the Alps.—Valleys that are here called "hanging" have frequently been described by observers in the Alps, but either without particular reference to their discordant relation to the main valleys, or with acceptance of normal erosion in the main valley as the cause of their discordance. Rüttimeyer's and Heim's views on discordant lateral valleys have been already referred to.

An account of the Salzachthal in the Tyrol, by Brückner, describes it as one valley in the bottom of another; the deeper one being relatively narrow and steep-sided, while the sides of the higher valley flare wide open; the side streams are described as falling into the deeper main valley; but this significant feature is not mentioned as if it were of general occurrence, nor is it explained by glacial erosion ('85, 95).

Lubbock, in his "Scenery of Switzerland," follows Rüttimeyer and Heim. After stating that the side valleys of the Reuss have a moderate grade which brings them out at the level of one of the terraces or *Thalstufen* of the main valley, from which their streams cascade down into the main stream, Lubbock writes: "It is obvious that this terrace represents a former 'Thalweg' of the Reuss with much less fall than it has now, and that the river has deepened its valley more rapidly than the lateral streams, so that these glens open at some distance up the side of the valley, and their waters join the Reuss by rapids or waterfalls. . . . The valley shows clear evidence of glacial action. The hard rocks are in places quite polished. This is especially the case with the buttresses which stand like doorposts where the lateral glens open into the main valley, and particularly on the right side of the eastern glens, the left of the western, where of course the pressure of the ice was greatest" ('96, 332, 334).

Russell on Hanging Valleys, 1887.—Russell gave a detailed account of what may be called hanging valleys in his report on the Quaternary History of Mono Valley, California. In a section on "high lateral cañons," he says: "In a number of instances in the Mono basin the low-grade glaciated cañons receive branching cañons at a considerable elevation above their bottoms, the branches also having a low grade. This is illustrated where Lake Cañon opens into Lundy Cañon. Each of these gorges has an approximately horizontal bottom near the place of union, but the former is a thou-

sand feet higher than the latter. The stream flowing through Lake Cañon descends precipitously over a rocky face in order to join Lundy Creek. The bottom of the higher cañon is about on a level with the main lateral moraine in the lower cañon. The same series of phenomena is repeated where Silver Creek descends over a rocky face to join Rush Creek. . . . It might be assumed that the main cañons had been excavated by glacial action more deeply than the lateral branches, owing to the greater eroding power of the glaciers which occupied them. This is a simple and natural explanation of the conditions observed, and if we admit the great amount of erosion usually assumed for ancient glaciers, it must be accepted as an adequate cause for the great strength of the main channels of ice discharge. To the writer . . . it appears that the main work of sculpturing in the Sierra Nevada . . . is to be attributed to water erosion, while only minor features . . . are to be referred to glacial action. With this conclusion in mind, the great inequality in the depth of the main glacial troughs and of their lateral branches, is too great a work to be ascribed to the erosive power of ice" ('89, 351-352).

The hanging valleys are therefore left without explicit explanation; but it appears from other pages of the report that several of the deeper canyons, such as Lundy, now head to the west of the general line of mountain crest, and it is therefore possible that they are examples of retrogressive erosion, both by water and by ice, since the elevation of the Sierra Nevada. If this be the case, the hanging valleys may be remnants of an ancient west-flowing drainage system, now diverted to a more rapid eastward descent. Some such meaning may be behind Russell's words: "Many of the valleys of the Sierra Nevada . . . are in fact relics of a drainage system which antedates the existence of the Sierra as a prominent mountain range" ('89, 348, 350).

Wallace on Glaciated Valleys, 1893. — One of the most appreciative statements that I have found concerning hanging valleys is an article by Wallace on "The Ice Age and its Work," which presents many arguments in favor of the strong erosive power of glaciers. Wallace says: "It is evident that ice erosion to some extent must have taken place along the whole length of the glacier's course, and that in many cases the result might be simply to deepen the valley all along, not quite equally, perhaps, but with no such extreme differences as to produce a lake basin." Then after giving much emphasis to the excavation of lake basins near the lower end of a large glacier, where the erosive power is deductively argued to

be at its maximum, Wallace examines several lakes to discover if those of glacial origin have not some distinctive feature by which they can be recognized. He points out that greater length than breadth, and simplicity of outline, are highly significant of glacial erosion, and that the absence of lateral bays and branches is strongly against the theory of warping or submergence. In this connection it is recognized that "the lake *surface*, not the lake *bottom*, represents approximately the level of the preglacial valley, and that the lateral streams and torrents enter the lake in the way they do because they could only erode their channels down to the level of the old valley before the ice overwhelmed it. . . . In connection with this subject may be noticed the many cases in which Alpine valleys present indications of having been greatly deepened by glacial erosion, although, owing either to the slope of the ground or to the uniformity of the ice-action, no lake has been produced. In some valleys, as in that of Lauterbrunnen, the trough between the vertical rock-walls was probably partly formed before the ice age, but was greatly deepened by glacial erosion, the result being that the tributary streams have not since had time to excavate ravines of equal depth with the main valley, and therefore form a series of cascades over the lateral precipices, of which the Staubbach is the finest example. In many other cases, however, the side streams have cut wonderfully narrow gorges by which they enter the main valley" ('93, 754, 768).

McGee's Second Paper on Glacial Canyons, 1894. — McGee has given a fuller statement of the action of glacial erosion in producing discordance between lateral and main valleys in a second essay, again entitled "Glacial Cañons," published eleven years after his first essay on this subject. After a discussion of glacial erosion in general, it is stated that "Glacial cañons are characterized by several peculiar features: 1. They are U-shaped rather than V-shaped in cross-profile; 2. Small tributary gorges usually enter at levels considerably above the cañon-bottoms; 3. In longitudinal profile the cañon-bottoms are irregularly terraced,—i. e., made up of a series of rude steps of variable form and dimensions,—and some of the terraces are so deeply excavated as to form rock-basins occupied by lakelets. . . . In a region of rapid corrasion then, the main [water] stream must . . . more rapidly corrade its channel than does its minor tributary; and the tributary cañon must accordingly enter its principal over a rapid or at least a convex curve in longitudinal profile. If now the main cañon become filled with ice and be

transformed from the V to the U type by its action, the distal extremity of the tributary will be cut off and the original stream-formed declivity replaced by the precipitous side-wall of the normal glacier valley" ('94, 351, 359). It is explicitly stated by McGee that this explanation does not demand great glacial erosion, because the U-canyon of glacial origin need not be much deeper, although significantly wider, than the preglacial V-canyon of river origin. But the last of the above quotations postulates a special condition — a region of rapid preglacial corrasion by streams, and in so far does not seem applicable to the case of the Ticino or of the many other Alpine valleys; for the well-opened slopes of the lateral valleys, and the still wider flare on the upper slopes of the main valleys in the Alps, proves that during their formation the main stream must have attained a graded slope which the lateral streams must have joined in accordant fashion; and there is nothing to show that the open and graded floor of the main valley was significantly trenched by river action in preglacial time. On the contrary, the shallowness of the trenches now found in the lateral hanging valleys proves that even if the main valley had been trenched, it could not have been cut down very deep.

Tarr on Cayuga Lake, 1894. — A significant instance of discordance has been pointed out by Tarr and taken by him as direct evidence of the glacial erosion of a lake basin. He shows that the north and south trough of Cayuga Lake, New York, lying in the line of ice motion, is about three hundred feet deeper than the floor of Salmon Creek, a tributary whose course is oblique to the ice motion; and he ascribes the break of grade between the two valleys to greater erosion in the deeper one. He generalizes so far as to refer to Lake Ontario as probably exhibiting further instances of discordant valleys ('94).

De Lapparent on Hanging Valleys, 1896. — A clear and brief statement is made by de Lapparent in his "Leçons de Géographie Physique," as if the matter were well known and undisputed. Under the heading, "Caractères des vallées glaciaires," he writes in effect as follows: "When a glacier disappears, the lateral valleys, which had been eroded before the glacial period with relation to the local baselevel determined by the river that the glacier afterwards replaced, may, on the disappearance of the ice, no longer present accordant junctions with the main valley. Cascades and rapids will therefore occur at their mouths in greater number than in a district of the same strength of relief which has not been glaciated.

All these features are clearly seen in Norway." ('96, 210; '98, 219).

Richter on Norway, 1896.—The essay by Richter already referred to contains a large number of excellent observations. Regarding our special subject, he states that many side valleys in Norway mouth high on the fiord walls, as if cut off in the deeper erosion of the main valleys; a similar relation being known in the Alps, but of less distinctness. The discordance of valley depth in Norway is thought to depend on the faster erosion of the main valleys by water or ice or both, when the side valleys and the uplands were occupied by slow-moving névé. The side streams descending from the floors of their hanging valleys have not yet cut even narrow clefts in the rock walls of the main valleys ('96, 177-179).

J. Geikie on Glacial Erosion, 1898.—The recent volume on "Earth Sculpture" by James Geikie gives a generally available access to the results of Richter's observations on Norway. The following quotation comes after a description of the rock walls of the fiords: "Numerous tributary waters, some of which are hardly less important than the head-stream, do indeed pour into the fiord, but they have not yet eroded for themselves deep trenches. After winding through the plateau-land in broad and shallow valleys their relatively gentle course is suddenly interrupted, and they at once cascade down the precipitous rock-walls to the sea. The side-valleys that open upon a fiord are thus truncated by the steep mountain-wall as abruptly, Dr. Richter remarks, as if they had been cut across with a knife. . . .

"If we admit that a fiord is simply a partially drowned land-valley, and that the profound hollow in which it lies has been eroded by river action, how is it that the side streams have succeeded in doing so little work? Why should the erosion of the main or fiord-valleys be so immeasurably in advance of that of the lateral valleys? Obviously there must have been a time when the process of valley-formation proceeded more rapidly along the lines of the present fiords and their head-valleys than in the side-valleys which open upon these from the fjelds. At that time the work of rain and running water could not have been carried on equally over the whole land, otherwise we should find now a completely developed hydrographic system—not a plateau intersected by profound chasms, but an undulating mountain-land with its regular valleys. . . . According to Dr. Richter, the remarkable contrast between the deep valleys of the fiords and the shallow side-valleys that open upon them from

the fjelds — the profound erosion in the former, and the arrest of erosion on the plateau — admits of only one explanation. While rivers and rapid ice-streams, flowing in previously excavated valleys, were actively engaged in deepening these, the adjacent fjelds were buried under sheets of *névé* In short, while rivers and glaciers were deepening the great valleys and making their walls steeper, the intervening mountain-heights were gradually being reduced and levelled by denudation. . . . It was somewhat otherwise in the Alps, where the hydrographic system, perfectly regular in preglacial times, was only slightly modified by subsequent glacial action. Yet even there erosion proceeded most rapidly along the chief lines of ice-flow. Were the great rock-basins of the principal Alpine valleys pumped dry we should find the mouths or openings of the side valleys abruptly truncated, and their waters cascading suddenly into the ice-deepened main-valleys. For, as Dr. Wallace has shown, it is the present lake-*surface*, not the lake-*bottom*, that represents approximately the level of the preglacial valley. In a word, erosion proceeded most actively in the main valleys, the bottoms of which have been lowered for several hundred feet below the bottoms of the side-valleys. Precisely the same phenomena are repeated in Scotland. Were all the water to disappear from the Highland lakes and sea-lochs, we should find waterfalls and cascades at the mouth of every lateral stream and torrent " ('98, 246-249).

It is evident from these extracts that the deepening of valleys is regarded as greatest where lake basins have been eroded beneath the preglacial valley floors; and this belief is explicitly expressed in the following extract from the latest edition of the same author's "Great Ice Age," the standard work on that subject: "Take the case of a glacier creeping down an Alpine valley and spreading itself out upon the low ground at the foot of the mountains. Let us suppose that, in the upper part of its course, the incline down which it moves is greater than the slope of the lower reaches of the valley. When the glacier attains the more gently inclined part of its course, it is evident that its flow must be retarded, and there will therefore be a tendency in the ice to accumulate or heap up. Now we know that the pressure of a body in motion upon any given surface varies with the degree at which that surface is inclined; as the inclination decreases the pressure increases. It follows from this that when the glacier leaves the steeper part of its course, and begins to creep down the gentler slope beyond, it will press with greater force upon its rocky bed, and this increased pressure will be further intensified

by the greater thickness of the accumulated ice. . . . The result of all this is the formation of a rock-basin, the deeper portion of which lies towards the upper end, just where the grinding force of the glacier is greatest" ('95, 228, 229).

It seems to me that too great emphasis is here placed on the erosion accomplished near the end of a glacier, as indicated by lakes, and not enough upon the deepening of the valleys up-stream from terminal lakes, as indicated by hanging valleys. It is also to be noted that de Lapparent, Richter, and J. Geikie all describe the hanging valleys of Norway as if their preglacial form had not been significantly changed, thus failing to bring clearly forward the fact that the valleys of today are the ice channels of the past, and that the larger and smaller channels must have normally discordant floors in a system of glacial drainage, just as they have in a system of river drainage, although to a much greater degree. The full analogy between ice and water channels, which throws so much light on the whole question of glacial erosion, was first clearly set forth by the two following observers.

Gannett on Lake Chelan, 1898.—The most complete statement of the general principles involved in the production of hanging valleys that I have found in print is in an article on Lake Chelan, in the Cascade Mountains of Washington, by Henry Gannett. Chelan is a long narrow lake occupying the distal two thirds of the deep U-shaped valley of the Stehekin River on the eastern slope of the mountains. It was occupied in the glacial period by a heavy ice stream, fifty or sixty miles long, and half a mile to a mile broad. The rock walls which enclose the valley are strikingly parallel to one another, without buttressing spurs; they rise 4000 to 5000 feet above the lake waters. Nearly all the streams which flow into the valley tumble over its walls in a series of cascades. "From all indications it appears that the ice must have been at least 3000 feet deep in this gorge of the Stehekin, since several of the smaller branches join the main glacier at that height above its bed."

Speaking of these features in a more general way, Gannett says: "A glacier is a river of ice, and it behaves almost precisely as a river of water does. Its effects upon its channel are almost precisely similar to those of a river upon its channel, excepting in the fact that all its operations are on a vastly greater scale. . . . A word of caution must here be interpolated. The channel of a river, in which its water flows, must not be confused with its valley, which it drains. The above comparison refers to the *channel* of a river

[or of a glacier], not to its valley. . . . The glacier moves down the gorge, scouring and cutting the bottom and sides as it travels. The ends of the mountain spurs are planed off instead of being trimmed to sharp, angular points, as is done by streams in gorges cut by them. . . . Where the main glacier is joined by a branch, the bed of the branch is commonly found to be at a higher level than the bed of the main glacier, because being larger and heavier the main glacier has greater cutting power; indeed, in many cases the beds of small branches are hundreds, or even thousands, of feet higher than that of the main glacier to which they are tributary. The parallelism between the glacier and the river in their channels is further illustrated by this fact. The surface of the ice in the main glacier and in the branch must have been at the same level, although the bottoms, as stated above, differ greatly in elevation. So it is with a river at the point of junction of branches. The surface of the water must be practically at the same level in all cases, but the bottoms of the channels differ by the difference in depth of the streams at their point of junction. This fact affords us a measure of the minimum thickness of the ice at any place. It cannot have been less than the vertical distance between the bed of the main glacier and that of the tributary, and, indeed, must in all cases have been greater, owing to the thickness of the tributary" ('98, 417-428, especially 418-420).

Penck on Alpine Valleys, 1899. — A no less explicit and detailed statement of the peculiar features of glacial channels and their relations to river channels was made by Penck at the meeting of the International Geographical Congress in Berlin, September, 1899. The discordance of lateral and main valley floors was described as a general feature of all the larger Alpine valleys within their glaciated areas. The possibility of explaining the discordance by faulting, as suggested by Rothpletz for the Linththal, was considered, but rejected. The contrasts of the glaciated and non-glaciated Alpine valleys were strongly emphasized. The excess of the depth in the main valley beneath the floor of the hanging laterals was taken as a minimum measure for glacial erosion, and the term "over-deepened," already adopted on earlier pages of this essay, was applied to valleys thus worn to a greater depth than would have been possible to normal rivers. The publication of Penck's address is awaited with interest.

Harker on Glacial Valleys in Skye, 1899. — A brief article by Harker on glaciation in Skye describes the valleys as eroded in massive gabbros, with U-shaped cross-section, especially in the upper

stretches, and frequently heading in a corrie whose floor may hold a small rock-basin tarn. In longitudinal profile, the floor of a valley often consists of two or three stretches of relatively gentle slopes, or sometimes of basin form and then holding lakes, separated by relatively sudden descents. Tributary valleys mouth at a considerably higher level than the floor of the main valley, ('99, 196-199).

Gilbert on Alaskan Valleys, 1899. — A valuable contribution to the origin of hanging valleys will be found in a report on the Harri-man Alaskan Expedition of 1899, to be published shortly. A general statement of results was made by Gilbert during the session of the Geological Society of America in Washington, December, 1899, when the importance of the hanging lateral valleys in the Alaskan fiords, and their bearing on the problem of glacial erosion, was clearly set forth.

Blanford on Scotch Glens, 1900. — The only article that I have found on hanging valleys in Scotland is by Blanford, "On a particular form of surface, apparently the result of glacial erosion, seen on Loch Lochy and elsewhere." The "particular form" here referred to is the smoothness of the sides of the Great Glen of Scotland, a feature that may be held analogous to the smooth rock walls of the Norwegian fiords, and to the spurless basal cliffs of the glaciated Alpine valleys. It is inferred that in preglacial time the streams of the lateral glens were separated by advancing spurs which buttressed the sides of the Great Glen. Now the spurs seem to have been truncated, producing the smooth and even sides of the glen, to which attention is especially directed. The lateral glens are described as at present opening a thousand feet above the floor of the Great Glen, whose smoothed sides are very little eroded by the descending tributary streams. The change from the inferred preglacial form is conservatively taken to indicate a glacial erosion of "at least 250 or 300 feet of rock" (1900, 198-204).

Hershey on Sierra Costa, California, 1900. An article by Hershey, already referred to above, is the latest contribution to the subject in hand. In following up a valley in the Sierra Costa in northwest California, it is at first V-shaped, with jagged ledges between sharp-cut ravines on the sides, and hardly wider at the bottom than the stream that drains it. On reaching the stretch once occupied by a local glacier, the valley becomes an open U-shaped trough, with smooth slopes free from ravines and spurs. Above the limit of glacial smoothing, the mountain sides are still deeply scored with ravines and jagged with outcropping ledges.

The] descent of a glaciated valley floor is effected by a series of steps; the stretches of more gentle fall alternate with almost precipitous falls where the floor is let down several hundred feet. Corries with tarns in their floors are well developed (1900, 42-57).

Several essays by Norwegian authors remain to be considered. It has not been possible to make reference to them without postponing the appearance of this paper, and consideration of them is therefore deferred to another occasion.

With all these new contributions to the subject, it may be expected that hanging lateral valleys and overdeepened main valleys will soon gain the importance that they deserve in geographical literature.

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PLATE 1.

Fig. A. Valley of the Ticino, looking up-stream to Giornico.

Fig. B. Cliffs beneath graded slopes, eastern arm of Lake Lugano.



Fig. A.



Fig. B.

2000 feet high, 1000 ft. wide

PLATE 2.

Fig. A. Cascade at the mouth of a hanging valley, eastern arm of Lake Lugano.

Fig. B. Sterling Fall, Milford Sound, New Zealand.

DAVIS. GLACIAL EROSION.



Fig A.

PLATE 2.



DAVIS. GLACIAL EROSION.

Fig B

PLATE 3.

Fig. A. The Strandfos, a cascade descending from a hanging valley to Sandven Lake, Norway.

Fig. B. Valley of the Romanche, Alps of Dauphiny.



Fig. A.



Fig. B.

PROG. BOSTON SOC. NAT. HIST., VOL. 29.

No. 15. — *Echinoderms from Puget Sound: Observations made on the Echinoderms collected by the parties from Columbia University, in Puget Sound in 1896 and 1897.*

BY HUBERT LYMAN CLARK.

THE collections of echinoderms made by parties from Columbia University in Puget Sound in 1896 and 1897 were placed in my hands for identification by the late Mr. N. R. Harrington. On account of the way in which the literature on the subject is scattered, and of the difficulty of securing specimens for comparison, I have had to ask the assistance of many zoologists; and I desire to express my thanks, for courtesies received in the preparation of this paper, to Dr. Bashford Dean, of Columbia University, Dr. H. P. Johnson, of the University of California, Dr. S. J. Holmes, of the University of Michigan, and especially to Professor Jacob Reighard, of Michigan. I am also greatly indebted to Professor G. H. Parker of Harvard University and to the authorities of the Museum of Comparative Zoology at Cambridge for the opportunity of examining the collection of Asteroidea there; and to Mr. J. E. Benedict of the Smithsonian Institution for the privilege of making comparisons with the collections of echinoderms in Washington. Professor A. E. Verrill of Yale has helped me greatly with the star-fishes, especially by sending me photographs of *Dermasterias* and *Pteraster*.

Unfortunately, there are almost no data with the specimens in the collection, so that it is possible to give very few facts as to where or when the specimens were taken, or as to the depth of water, character of bottom, color in life, etc. Most of the specimens are labelled simply "Puget Sound, 1896" (or 1897, as the case may be). In March, 1897, Mr. Harrington and Mr. B. B. Griffin published in the Transactions of the New York Academy of Science some "Notes upon the Distribution and Habits of Some Puget Sound Invertebrates," from which I have succeeded in getting a little information regarding the distribution of some of the forms given in the present list. From the fact that Messrs. Harrington and Griffin mention seven holothurians and no less than five species of *Asterias*, it is clear that a considerable number of echinoderms were met with which are not represented in the collec-

tions I have examined. There are before me, altogether, 30 specimens of holothurians, representing 4 species; 14 echinoids, representing 8 species; 9 ophiuroids, representing 3 species; and 76 asterids, representing 10 species; a total of 129 specimens, representing 25 species. The echinoderm fauna of the Pacific coast of North America needs careful investigation and thorough revision. Many of the species are inadequately described, while almost nothing is as yet known of the holothurians. Most of the echinoderms that are known were originally described either by Brandt or by Stimpson, and never have been properly figured, many of them not at all. The only attempt at a local list of echinoderms from the neighborhood of Puget Sound which I have found, is a list of 17 species (the smaller holothurians were not identified) prepared by Mr. Whiteaves of the Canadian Geological Survey, based on a collection made along the coast of British Columbia (Trans. roy. soc. Canada, iv, 1886). Most of that collection were star-fishes, several of which do not appear in the following list. At the present time only about thirty or thirty-five species of echinoderms are known from the Puget Sound region. The collections made by the Columbia parties are therefore of considerable importance, and though the number of species represented is rather small, the majority are of more than usual interest.

ASTEROIDEA.

The star-fishes comprise more than half of the collection and are of much interest, no less than three being new to science, and several others having their range considerably extended. The following list of ten species represented is remarkable, not only for some of the species included, but also for the absence of some which would naturally be expected to occur in Puget Sound. The identification of the star-fishes has been a matter of considerable difficulty on account of the brevity of the original descriptions and the absence of type specimens for comparison. This is especially true of the members of the genus *Asterias*, and a careful revision of the Pacific coast species of that genus is most certainly a desideratum.

***Dermasterias imbricata* (Grube). Plate 1.**

There is one small star-fish in the collection, which is labelled "*Dermasterias imbricata* juv., Puget Sound, 1896," but there are no other data with it. It is very dark brown in color and only 14 mm. across. There is also a single, much larger specimen which is clearly a *Dermasterias* and which is almost certainly Grube's species. As a detailed description and figures of that species do not appear to have been published, I give the following description of this specimen.

Rays 5. $R:r::64\text{ mm.}:18$. $R=3r$. Rays rather long, broad at base; interbranchial arcs deep. Abactinal surface rather high (13 mm.), and rays not sharply set off from disc. Actinal surface almost flat. Both surfaces covered with a thick membrane, without spines anywhere. Membrane contains numerous flattened lime spicules (Plate 4, fig. 4), in the shape of rods or perforated plates. Marginal plates almost smooth, without spines or even granules of any sort, about 22 in number on each side of each ray. Adambulacral plates (Plate 4, figs. 2 and 3) with one stout, blunt spine at edge of furrow; near tip of ray there is another spine back of this and the two are of approximately equal size. Near tip of ray these spines form two series on each side of furrow and are independent of each other, but toward the base the outer row disappears and its place is occupied by a ridge of skin without spines. The spines of the furrow margin increase in size toward the base of the ray, where they reach a length of 2 mm. and are connected with each other by a fold of skin and each spine ends in a soft fleshy knob. Membrane of both surfaces very smooth, thick and tough. No transverse furrows on actinal side. Madreporite plate single, about 2.5 mm. in diameter, sunk below the membrane, smooth, with irregularly radiating ridges. Papulae numerous, arranged in groups of 5 to 17; on rays there are 6 longitudinal rows of such groups. There are none on the actinal surface. Feet stout, in two rows, yellow in alcohol. Color (in alcohol) yellowish brown, duller above; where membrane is torn off the color is a pale reddish purple.

***Solaster endeca decemradiata* Brandt.**

There are three large dried specimens and three very small alcoholic specimens before me. Of the dried ones, one has the rays about 60 mm. long, and there are but 9; the other two have 10 rays each, and these are about 100 mm. long. Of the alcoholic specimens, one is 14 mm. across (disc 8 mm.) and has 12 rays, and each adambulacral plate bears 3 spines; another is 27 mm. across (disc 11 mm.) and has only 9 rays, and there are 3 or 4 adambulacral spines; the third is 32 mm. across (disc 13 mm.) and has 13 rays, and most of the adambulacral plates carry 4 spines. In the light of recent

investigations which show that the size of a star-fish is no criterion of its age, it becomes an interesting question whether the number of rays in this (and allied) species is dependent on the age of the individual, so that the older specimens have the fewer rays. The life history of this species would prove of exceptional interest, and it is to be hoped it will be worked out before long.

***Pteraster multispinus* sp. nov.** Plate 3, figs. 1 and 2.

Rays 5. $R:r::27\text{ mm.}:18$. $R=1\frac{1}{2}r$. Breadth of ray at base 17 mm. Interbrachial arcs rather shallow. Disc almost flat, 10 mm. high, the rays not clearly marked off. Abactinal surface of rays almost flat; actinal surface flat, edges rounded. Supradorsal membrane thick, stout and apparently muscular, with no sign of reticulations. Spiracula seem to be absent on disc, but abundant near tips of rays. Paxillae high with numerous spines (8-10 or more), those in the middle little more slender than those on edge of paxilla. On account of the abundance of paxillae spines, it is almost impossible to determine whether the membrane contains any other calcareous bodies or not, but there seem to be none. Oscular orifice large, surrounded by long spines imbedded in the membrane. Ambulacral furrows broad; feet in 2 rows. Adambulacral plates with 6 spines, arranged in a row at right angles to furrow and united by a delicate membrane. The outermost spine is clearly united to the fifth by this membrane, and each series of spines is united by this membrane to the edge of the supra-dorsal membrane. Between each pair of outermost spines is a small sharp spine, the aperture papilla, which is nearly free on both sides. Mouth plates prominent, each with 3 marginal spines united by a delicate membrane, and with a very large, free, superficial spine, placed near the base, and pointing downward and backward. Color, in alcohol, grayish pink-purple.

The single specimen of this interesting form bears no other label than the date "1897." Unfortunately there is no clue as to the exact locality or the depth at which it was collected. It is somewhat damaged, but seems to be very distinct from any species of the genus hitherto described. The only other *Pteraster* known from the North Pacific is *P. aporus* Ludw., collected in Behring Sea, which is characterized by the absence of an oscular orifice, so obvious in the present species. The name given has been selected on account of the large number of spines on each paxilla.

***Retaster gracilis* sp. nov.** Plate 3, figs. 3 and 4.

Rays 5. $R:r::16:8$, or $18:9$. $R=2r$. Breadth of arm at base equals r . Interbrachial arcs deep. Disc depressed, 6-8 mm. high, the rays not clearly marked off. Abactinal surface of rays rather arched; actinal surface flat, but edges rounded. Supradorsal membrane very thin and delicate; the tips of the spines from the edges of the paxillae connected by delicate lines giving the

abactinal surface a reticulated appearance. This is much more evident in the smaller specimen, the lines in the larger specimen being very indistinct. Spicules seem to be entirely wanting in the membrane. Spiracula quite numerous, 6 to 10 in each mesh of the reticulum. Paxillae high, with 6 or more (often many more) spines surrounding edge and several smaller ones erect in middle. Oscular orifice present, but not especially noticeable. Adambulacral plates with 6 spines arranged in a row at right angles to furrow. Of these the first is very small, the second larger, the third still larger, the fourth still larger, the fifth equals the third, while the sixth is largest of all. The first five are united by a delicate membrane, but the sixth is almost wholly free. The sixth spines of all of the adambulacral plates are united with each other by a membrane parallel to the ambulacral furrow, and this is apparently separate from the supra-dorsal membrane. Aperture papillae very small, and free only on one side. Mouth plates prominent, each with 2 spines on edge, united by a membrane, and a very large spine on oral surface near base, pointing downward and outward. This spine is free and not connected with anything else by a membrane. Ambulacral furrows broad; feet comparatively few, in two rows. Color of whole star-fish, light brownish gray, darkest on disc, lightest near tip of rays.

There are two small specimens of this graceful little star-fish, but there is nothing to indicate where or when they were taken. The smaller of the two specimens seems to have the characters of *Retaster* fairly well marked, but the larger is much more like *Pteraster*. Not being able, however, to find any spicules in the supradorsal membrane in either specimen, it seems best to put them in the former genus. No specimen of *Retaster* has hitherto been recorded from the North Pacific, nor indeed from any point nearer to Puget Sound than the northeast coast of Australia. The name *gracilis* has been chosen for this species on account of its very delicate structure and beauty of form.

***Cribrella laeviuscula* Stimpson.**

There seem to be two well-marked varieties of this species, one with short, stout rays, the other with the rays long and slender. Dr. H. P. Johnson tells me that the two forms intergrade, but in the collection before me there are no intermediate specimens. There is only one specimen of the slender variety and in that one $R = 5 r$. In the 25 specimens of the other variety, $R = 3\frac{1}{2} r$ or less. Dr. Johnson has suggested the names *crassa* and *attenuata* for these two forms. They may be characterized thus :

C. laeviuscula crassa. Disc large; rays short and stumpy, terete, thick at base. $R = 2-3\frac{1}{2} r$.

C. laeviuscula attenuata. Disc small; rays long and slender, flattened below. $R = 5-6$ r.

***Cribrella spiculifera* sp. nov. Plate 2.**

Rays 5. $R:r:: 64\text{ mm} : 14$, or $77\text{ mm} : 15$. $R = 5$ r. Breadth of ray near base about 19 mm. Rays somewhat tumid near base, but tapering quite rapidly to a rather attenuate tip; somewhat narrowed at base, and with rather deep interbranchial sulci. Plates of abactinal surface rather large and not closely crowded, the groups of papulae being much more numerous than in *C. laeviuscula* or *oculata*. The plates are irregularly rounded, or crescentic with the concave side toward the centre of the disc. They are irregularly scattered and show no evidence of arrangement in rows, except along the sides of the rays, where they assume a longitudinal arrangement. Near the tip of the ray, on each side, are 3 longitudinal rows, the lowest of which consists of small plates lying close to the adambulacral plates and running parallel to that series the whole length of the ray. The two other rows consist of larger plates, and the lower of the two runs the whole length of the ray parallel to the row of small plates. The upper one, however, diverges from the lower about the middle of the ray and runs upward toward the abactinal side of the disc, where it joins the corresponding row of the next ray. The narrow triangular space between this upper row and the lower one is filled by 3 or 4 short irregular rows of somewhat smaller plates. Toward the tip of the ray the plates of the 3 longitudinal rows are arranged in more or less regular transverse series, but this arrangement is wanting near the base of the ray. Spinelets very numerous on all the abactinal plates, rather longer and more slender than in *laeviuscula*, measuring .3 mm. in length. The abactinal plates are so much less crowded and the spinelets are so much more numerous and slender than in *laeviuscula* that the surface does not appear granular, as it does in that species. Adambulacral plates (Plate 4, fig. 1) with a single, stout spine, .75 mm. long, high up in the groove, and with 25-30 spinelets on the actinal surface. These spinelets are arranged in 6 or 7 series parallel to the ambulacral furrow, with 3 or 4 spinelets in each series. The spinelets on the edge of the furrow are largest, measuring 2 mm. in length, and each successive series consists of smaller ones, the last series being very small. They are all closely crowded together. Madreporic plate single, small (2-3 mm. in diameter), covered with spinelets arranged in 10-12 rows, radiating from the centre. Color of alcoholic specimens, uniform dark gray, with a slight yellowish tinge in some lights.

There are two large specimens of this new *Cribrella* which is so different from the preceding species, but again we are confronted by the absence of data as to where and at what depths they were collected. This species does not seem to be related very closely to any previously known one, being easily distinguished by the large number of spines on the adambulacral plates. In size and general form it resembles *C. obesa* Sladen from the Straits of Magellan, while in the armature of the adambulacral plates, *C. com-*

pacta Sladen, from New Zealand, would seem to be its nearest ally. The name *spiculifera* was selected for this species on account of the numerous little spines all over the abactinal plates, as well as those on the adambulacra.

***Echinaster tenuispina* Verr.**

There are three dried specimens of an *Echinaster* in the collection, which I have referred with some hesitation to this species, although its known range is thereby extended considerably to the north. The specimens before me are dark red; and the rays are long (52–62 mm.) and very slender, and though rough, they are not spiny.

? *Asterias hexactis* Stimpson.

There are 31 specimens of a small star-fish, varying in size from $R = 16$ mm. to $R = 43$ mm. $R = 3-3\frac{1}{2}$ r. All of the specimens have 6 rays. The latter vary in width very much, so that there are two varieties, similar to those of *Cribrella laeviuscula*, one with stout, the other with slender rays. The extremes are represented by two specimens of approximately equal size, in one of which R : breadth of $R :: 24$ mm.: 9, while in the other R : breadth of $R :: 24$: 6. In the can containing this and the following species is a label reading "*Asterias aequalis* Stimpson." I have compared the specimens with Stimpson's description and do not think they can possibly belong to that species. It seems to me that they are probably his species *hexactis*, which was originally collected in Puget Sound.

***Asterias ochracea* Brandt.**

There are two large but badly mutilated specimens, apparently of this species, in which $R:r :: 110$ mm.: 18.

***Pycnopodia helianthoides* (Brandt).**

One very large specimen with 20 rays, measuring 45 cm. across, labelled "Port Townsend, Wash., 1896." Mr. Harrington says this is "the commonest sea-star at Port Townsend," and speaks of "a few specimens with 24 arms, being found."

OPHIUROIDEA.

There are only nine representatives of this group in the entire collection; and, although preserved in alcohol, they are all more or less broken and imperfect.

***Ophioglypha lütkeni* Lym.**

There are five specimens of this species, varying from 4 to 17 mm. across the disc. Only one has the scales on the disc noticeable and overlapping, or shows any variegation in the color of disc and arms. The others are uniformly smooth and light.

***Ophiopholis caryi* Lym.**

There are three specimens of this form, 6, 7, and 9 mm. across the disc. Color pinkish purple; arms slightly banded; under side of arms, and ring around mouth, almost white.

? *Amphiura urtica* Lym.

There is one specimen of an *Amphiura* with most extraordinarily long arms. The upper half of the disc is gone, so that it is impossible to determine its original size or decide positively to what species the specimen belongs. At the present time the disc is only 6 mm. across, while the rays measure 300 mm. Color, in alcohol, light yellowish gray. I suspect that this is an undescribed species, but it seems better at present to consider it simply as a mutilated specimen of *urtica*.

ECHINOIDEA.

Although none of the Echinoidea in the collection are new to science, several of them are of interest because their occurrence in Puget Sound considerably extends their known geographical range. All of the echinoids before me are dried specimens.

? ***Arbacia stellata*** (Blainv.).

There is a denuded test, 40×19 mm., pale brown in color, which is clearly an *Arbacia* and probably belongs to this species, though Puget Sound is somewhat north of its known range.

Diadema mexicanum A. Ag.

There is a single example of a *Diadema* in which all the spines are broken. It measures 65 mm. in diameter. Although Puget Sound is north of the known range of the species, there seems no doubt that the specimen is one of *mexicanum*.

Strongylocentrotus purpuratus (Stimpson).

There is a denuded test of this species, 51 mm. in diameter, and three other specimens, from 38 to 46 mm. These four specimens vary in color from light greenish to bright purple. The coronal plates are 16, 18, 18, and 19, respectively, from smallest to largest. The spines vary from 7 to 12 mm. in length. The pores are 8 or 9 pairs in each zone at ambitus, where they are nearly horizontal; above ambitus there are 8 pairs, and they are more nearly vertical.

There is also a small urchin, only 22 mm. in diameter and 12 high, with spines 6–8 mm. long and only 13 coronal plates. The color is very pale. There are only 6 or 7 pairs of pores, and they are nearly vertical even at ambitus. It is possible this is a small specimen of *S. franciscanus* A. Ag., but it is probably a young *purpuratus*.

Strongylocentrotus dröbachiensis (Müll.).

A single specimen (80 mm. in diameter) and fragments of two others of this cosmopolitan species are in the collection. The test is dark purple, and the short spines (10–12 mm.) are light green.

Echinometra oblonga (Blainv.).

There is one very good specimen of this handsome species, which agrees perfectly with specimens in the National Museum. It is 73 mm. long \times 58 wide \times 24 high. The spines are very numer-

ous, dark olive green, and quite stout. The occurrence of this species in Puget Sound extends its range eastward many hundred miles, as the Sandwich Islands have hitherto been supposed to mark its eastern limit.

? *Toxopneustes semituberculatus* (Val.).

There are two denuded tests of a *Toxopneustes*, apparently referable to this species, but resembling *T. variegatus* in some particulars. The actinostome is small (14–15 mm. across), and there seems to be no granulation of the bare ambulacral and interambulacral spaces. The specimens are 40 and 45 mm. in diameter, and the coronal plates are 23 and 25 in number, respectively. The occurrence of this species in Puget Sound extends its known range considerably to the northward.

***Clypeaster rotundus* A. Ag.**

There are two specimens of a *Clypeaster*, very similar to specimens of *subdepressus* from the West Indies, but undoubtedly referable to *rotundus*, thus extending the known range of this species considerably to the northward. The specimens measure 120×100 and 97×86 mm.

***Echinarachnius excentricus* (Esch.).**

There is a single denuded test of this species, 84×81 mm. Mr. Harrington speaks of this as the most abundant and characteristic echinoid of the sand flats near Port Townsend. He says that the sand was thickly packed with them, and that "fully 80 per cent had the pointed side directed vertically or obliquely downward." He also speaks of collecting this species in Hood's Channel and at Neah Bay.

HOLOTHURIOIDEA.

Although there are only four species of holothurians in the collection, two of them are new to science and the other two are very incompletely known, and have hitherto been recorded from only a single locality. The material is not in the best of condition, except-

ing the specimens of *Psolus*; and, also excepting that species, the number of individuals is unfortunately small.

? *Synapta albicans* Sel. Plate 4, fig. 5.

There are two very small specimens of a *Synapta*, which I assume were dredged in Kilisut Harbor (Scow Bay). At least, Mr. Harrington says that two synaptas were dredged in Kilisut Harbor, and, as these are the only synaptas in the collection, I assume that they are the two referred to. One is a fragment, 30 mm. long, without head or tail, while the other, though only 25 mm. long, seems to be a complete individual, and is apparently sexually mature. These specimens resemble small specimens of *S. inhaerens* in shape, number of tentacles and digits thereon, shape of calcareous ring, and in the general internal anatomy. The anchors and plates are indistinguishable from those of *inhaerens*. The miliary granules (Plate 4, fig. 5), however, are like those of *roseola*, and are present only in the longitudinal muscles. There are no sense-organs of any kind on or near the tentacles. Verrucae are numerous, small and colorless. These specimens are pale flesh-color, and there are no pigment spots in the skin. *S. albicans* was described by Selenka from specimens collected at Mendocino, Cala. The only characters given in his description which would serve to distinguish the species from *inhaerens* were the number of digits on the tentacles (21 in his specimens) and the absence of a loop in the intestine. He gives no clue to the size of the animal. The specimens before me differ from Selenka's in both these particulars, for there seem to be only 9 digits on the tentacles, and I could not see that the intestine differed at all in arrangement from that of *inhaerens*. It seems to me more than possible that the specimens from Puget Sound are young individuals of Selenka's species. We know that in some synaptas the number of digits on the tentacles increases with age, and that fact may account for the discrepancy between the Mendocino and Kilisut specimens. If they belong to the same species, as I have assumed, it may be easily distinguished from *inhaerens* by the absence of the sense-cups on the tentacles, though Selenka does not refer to that fact. At any rate, it seems to me better to regard these two specimens as *albicans* than to base a new species on such slight differences, with so little material at hand.

Cucumaria chronhjelmi Théel. Plate 4, figs. 11–20.

There are two specimens of a *Cucumaria*, almost pure white in color, which doubtless belong to this species described by Théel from specimens collected at Vancouver. One is about 70 mm. in length, the other about 40. The pedicels are very long (5 mm.), and form two very distinct rows along each ambulacrum (fig. 20). There are none on the interambulacra. The tentacles are completely retracted so that their relative proportions cannot be positively determined. The body wall, as well as the pedicels, is made very firm by the crowded deposits. These have been quite fully described by Théel, but unfortunately he published no figures, without which it is hard to form any accurate idea of holothurian spicules. The deposits in the specimens before me do not wholly accord with Théel's description, yet I feel sure I am dealing with the same species. In the specimens from Puget Sound, there are at least seven different kinds of deposits, and the more important of these I have figured (figs. 11, 12, 15–18). They are as follows: (1) supporting rods in the tentacles; (2) supporting rods in the pedicels; (3) terminal plates in the pedicels; (4) large, knobbed, perforated plates; (5) large, smooth, perforated plates; (6) smaller knobbed buttons or hollow ellipses; (7) small reticulated baskets. The baskets lie in the outermost layer of skin and are quite abundant; while some are simple open cups, many have the edges grown together over the centre, forming a long spire ending in two flaring teeth, and this spire projects outward through the skin. Below the baskets is a thick and very dense layer of the buttons, ellipses and plates. The large plates and the ellipses are quite uncommon, the great bulk of this layer being formed from the smaller, irregular, knobbed and perforated buttons. Besides these slight differences which I find in the deposits in the skin, I notice also a difference in the calcareous ring. Théel says the calcareous ring is very delicate, whereas in the Puget Sound specimens it is well developed and quite large. This is perhaps a difference of degree rather than of kind. In all other particulars his description would answer for the specimens before me.

Cucumaria lubrica sp. nov. Plate 4, figs. 21–28.

Body short, cylindrical, rather blunt at both ends, the surface very smooth. Pedicels in a double row along each ventral ambulacrum, but there are also

many scattered pedicels on the spaces between. On the dorsal surface the rows along the ambulacra are less distinct, while the scattered pedicels are very few (fig. 21). Pedicels short, with few supporting rods in the walls. Tentacles 10, their relative size doubtful. In one specimen, in which they are most easily examined, the four dorsal ones are long and slender (4-5 mm.), while the other six are short and stumpy (2 mm.). But this peculiar arrangement may be wholly due to the manner and degree of contraction. The genital glands are well developed and consist of numerous, long (30 mm.), unbranched filaments. The respiratory trees (fig. 28) are very noticeable on account of the short branches, somewhat enlarged at the tips. These tips, in the specimens before me, are brown, while the rest of the tree is yellow, so that they are very conspicuous. The muscles and digestive system show no unusual features. Stone-canal small and single. Polian vessel one or none. Calcareous ring (fig. 22) very small and delicate, not one third the size of that of *C. chronhjelmi*. Radial pieces broad, deeply notched behind, but with no long posterior prolongations. Interradial pieces broad, but with a long, narrow, anterior prolongation. Tentacles with large, broad, supporting rods (fig. 23). Pedicels with a few, peculiar, curved, supporting rods, bearing two projections on the convex side; the rod with from one to several holes in each end (fig. 24). In the body wall numerous, thick, knobbed plates or buttons, in all stages of development; most of them are nearly elliptical or even spherical, but others are more flattened. The simplest ones (fig. 25) are small, thick plates with four symmetrically placed holes; others, somewhat larger, are very much knobbed; while in the great majority (fig. 26) the knobs have so fused into ridges and overgrown the plate that the holes are quite small and irregularly scattered. There seem to be no other deposits in the body wall. Color pale grayish brown; pedicels brown. Length from 10 to 40 mm.; the largest, 12 mm. in diameter.

There are seven specimens of this little holothurian, but there are no data to tell us anything of its habits or habitat. The specimens are all very much contracted, so that it is not possible to determine exactly the proportions of the tentacles nor the size of the pedicels. In general appearance, arrangement of the pedicels, and shape of the calcareous ring, this species resembles *C. regiae* Théel; but it differs very markedly from that form, in the calcareous deposits. Indeed it differs in that particular from all the forms known from the eastern Pacific, and does not seem to be closely allied to any known *Cucumaria*. The name *lubrica* has been selected for this species on account of the unusual smoothness of the surface of the body.

***Psolus chitonoides* sp. nov.** Plate 3, figs. 5 and 6. Plate 4 figs. 6-10.

This very well-characterized form is represented in the collection by nineteen specimens, ranging in size from 16 × 14 mm. to 63 × 44. They are much

flattened, the largest one being only 16 mm. high. Upper surface covered by firm plates, evidently imbricated in the very small specimens, but not in the large ones. In the smallest specimen there are about three hundred plates, but more than two thirds of these are very small plates arranged in about three rows around the margin; of the remainder, 20 are included in the oral area and 10 in the anal. In the largest specimens the number of plates is considerably greater, there being 30 plates in the oral, and 20 in the anal area. But several features are common to all the specimens, regardless of size. The plates are so finely granulated that they feel smooth and appear so to the naked eye. The anus is closed by 5 or 6 large plates and several small ones, while the mouth is guarded by 5 broad triangular plates, alternating with 5 long narrow ones which lie beneath them. Between the oral and anal areas there are about four transverse rows of large plates. None of the plates, either on the margin or elsewhere, are pitted, or perforated for the passage of either pedicels or papillae. Ventral surface almost flat, depressed below edge of shell. Pedicels arranged around margin in three or four rows (in very small specimens two rows), and with a fairly well-defined double row down the middle of the disc. This middle series is wanting or is very indistinct in the smallest specimens. There is also a single row of smaller or imperfect pedicels close to the margin of the disc, on the under side of the marginal plates of the dorsal surface. Retractor muscles strong. Intestine long and much coiled. Respiratory trees very unequal, the right one much longer. Cuvier's organs wanting. Reproductive gland, of numerous, long, unbranched filaments. Polian vessel one, short and globular. Stone-canal one, on left side, somewhat pear-shaped, more or less attached to mesentery. Calcareous ring (fig. 6) without posterior prolongations, the radial and interradial pieces of approximately equal size. Tentacles 10, plentifully filled with supporting rods (fig. 7) even to the tips of the branches, where they are very small (fig. 8). Pedicels with terminal plates and long, narrow, knobbed, perforated plates (fig. 9) well filling the walls. The skin of the ventral surface is thin and somewhat translucent, but is thickly crowded with calcareous plates (fig. 10) which are easily seen with a small magnifying glass. These plates are generally more or less elliptical, very much perforated with minute holes, and with numerous, low, rounded knobs all over them. Others have an irregular and low spire, of no very definite shape or position. These plates seem to be confined almost wholly to the ventral surface. Color very pale pinkish white; tentacles bright flesh-red. The latter are much contracted, and their appearance gives the impression that the color of the rest of the animal has faded in the alcohol.

There are no data with these specimens, but I believe they were collected at Neah Bay, as Mr. Harrington speaks of collecting a *Psolus* at that point. They are all much contracted, and in their contracted condition they look not a little like chitons, and for that reason, the name selected has been given them. This species resembles *P. operculatus* of the Caribbean Sea in some particulars, but differs from it quite markedly in the absence of granulation, the arrangement of the feet, and the deposits in the sole. It is the first

true *Psolus* to be recorded from the western coast of North America, although *P. fabricii* and *P. japonicus* are known from the other side of the Pacific.

In concluding this report, it may be said that its chief value lies in the interest which it ought to arouse in the echinoderms of the Pacific Coast. A wide field for investigation lies open there, which should be occupied at once, and the mission of this paper will be performed if it serves as a stimulus to a proper investigation of that field.

OLIVET COLLEGE, MICHIGAN,
May 1, 1900.

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PLATE 1.

Dermasterias imbricata (Grube). Nat. size.

Fig. 1. Abactinal surface.

Fig. 2. Actinal surface.



CLARK.—Puget Sound Echinoderms.

PLATE 2.

Cribrella spiculifera sp. nov. Nat. size.

Fig. 1. Abactinal surface.

Fig. 2. Actinal surface.

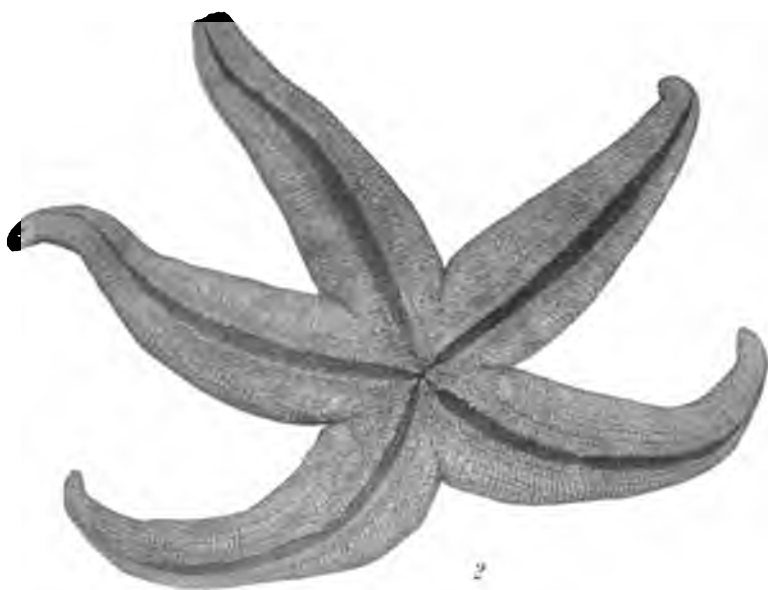
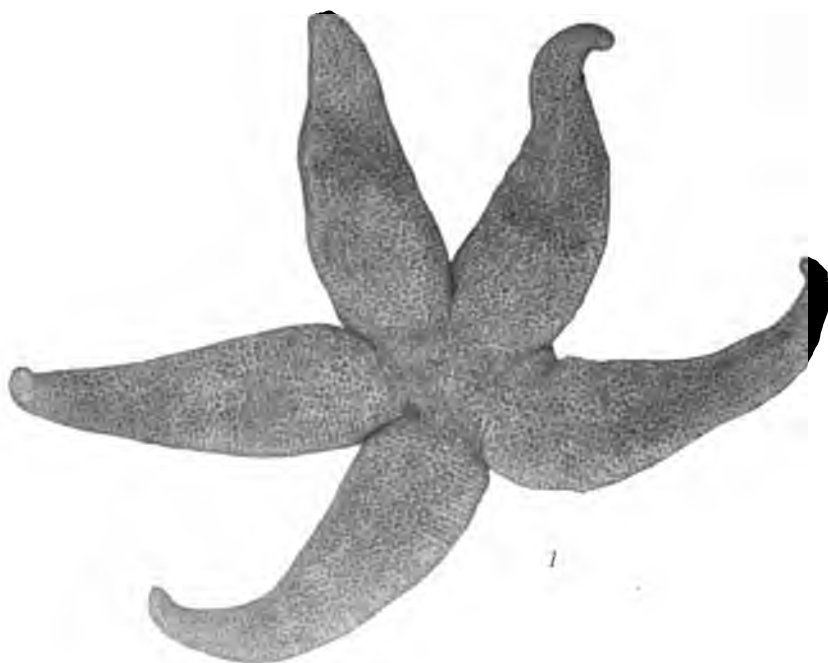


PLATE 3.

Figs. 1-2. *Pteraster multispinus* sp. nov. — Abactinal and actinal surfaces.

Figs. 3-4. *Retaster gracilis* sp. nov. — Abactinal and actinal surfaces.

Figs. 5-6. *Psolus chitonoides* sp. nov. — Upper and lower surfaces.

(All these figures are natural size.)



PLATE 4.

Fig. 1. *Cribrella spiculifera*.—Three adambulacral plates, showing the armature. $\times 5$.

Figs. 2-4. *Dermasterias imbricata* (Grube).

Fig. 2. Eight adambulacral plates, from near tip of ray, showing the two rows of spines. $\times 5$.

Fig. 3. Four adambulacral plates from near base of ray, showing the spines and the fleshy ridge. $\times 5$.

Fig. 4. Calcareous spicules from the membrane of the abactinal surface. $\times 78$.

Fig. 5. (?) *Synapta albicans* Sel.—Miliary granules from the longitudinal muscles. $\times 310$.

Figs. 6-10. *Psolus chitonoides* sp. nov.

Fig. 6. Interradial and radial pieces of calcareous ring. $\times 3$.

Fig. 7. Supporting rods from tentacles. $\times 78$.

Fig. 8. Supporting rods from tips of tentacle branches. $\times 78$.

Fig. 9. Supporting plates from pedicels. $\times 78$.

Fig. 10. Perforated plate and incomplete table from sole. $\times 78$.

Figs. 11-20. *Cucumaria chronhjelmi* Théel.

Fig. 11. Supporting rods from tentacles. $\times 78$.

Fig. 12. Supporting plates from pedicels. $\times 78$.

Fig. 13. Radial piece of calcareous ring. $\times 5$.

Fig. 14. Interradial piece of same. $\times 5$.

Fig. 15. Large plates from body wall. $\times 78$.

Fig. 16. Common knobbed button. $\times 78$.

Fig. 17. Reticulated basket or cup, seen from below. $\times 310$.

Fig. 18. Basket with spire, seen from the side. $\times 310$.

Fig. 19. Small branch of the respiratory tree. $\times 5$.

Fig. 20. Band of skin from middle of body, laid flat to show the arrangement of pedicels. Nat. size.

Figs. 21-28. *Cucumaria lubrica* sp. nov.

Fig. 21. Band of skin from middle of body, laid flat to show the arrangement of pedicels. Nat. size.

Fig. 22. Interradial and radial pieces of calcareous ring. $\times 5$.

Fig. 23. Supporting rod of tentacle. $\times 78$.

Fig. 24. Supporting rods from pedicels. $\times 78$.

Fig. 25. Perforated plates from body walls. $\times 78$.

Fig. 26. Common perforated ellipse or button. $\times 78$.

Fig. 27. Same, seen from one side. $\times 78$.

Fig. 28. Branch of the respiratory tree, to show the difference in shape of the branches in *lubrica* and other holothurians, as illustrated by *C. chronhjelmi*, fig. 19. $\times 5$.



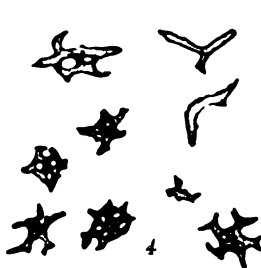
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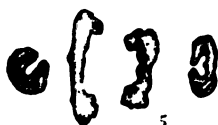
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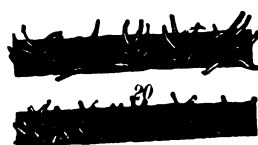
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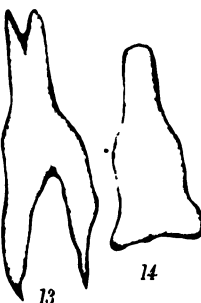
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No. 16. — *Bermudan Echinoderms. A Report on Observations and Collections made in 1899.*

BY HUBERT LYMAN CLARK.

THE following notes on the echinoderms of Bermuda are based on the collections made by the New York University party in June and July, 1899, and on personal observations made in April of the same year during a two weeks' visit to the islands. I wish to express my great obligation to Mr. F. W. Carpenter for the care with which the specimens were prepared, and for his valuable field notes, which add so much to the interest of the collection. The University party was stationed during this, its third visit to Bermuda, on White's Island, in Hamilton Harbor, between the city and the Paget shore. My own observations were made at Bailey's Bay, on the north shore, where the University parties of 1897 and 1898 had been located.

No new star-fishes, brittle-stars, nor sea-urchins were added to the list during the past summer, but several specimens of the large star-fish, *Luidia clathrata* (Say) were collected on the beach at White's Island. The only previously recorded specimen was taken in Harrington Sound in 1898, and was said to have been "salmon-pink" in color when alive. The specimens taken this year are all bluish gray above and cream color beneath, the normal color of this species. It would be interesting to know whether the *Luidias* in Harrington Sound are always differently colored from those in Hamilton Harbor. My observations on the more common star-fish, *Asterias tenuispina*, seem to show that in that species the specimens from the Sound differ from those collected on the north shore. The number of arms was noted in all the individuals seen, and as these were all collected in two places some distance apart, the result is interesting. One of these places was on the north shore at Coney Island, near the bridge, and here eleven specimens were found. Of these, six had six arms, three had five, and two had seven. The other locality where *Asterias* was collected was on the northwest shore of Harrington Sound. Of twenty-nine individuals collected here, fourteen had seven arms, six had eight, three had six, three had five, two had nine, and one had apparently only four. In all

but one of these twenty-nine the arms were of very unequal size, those with eight and nine having three or four large arms and the others quite small. It will be seen from these figures that the star-fishes from Coney Island average 5.91 arms each, while those from Harrington Sound average 6.93. In other words, 82% of those from Coney Island had six arms or less, while this was true of only 24% of those from Harrington Sound. The number of star-fishes examined was too small to warrant any conclusions being drawn, but the facts are interesting, and make further investigations desirable. Of the other star-fishes which I collected, *Asterina folium* was rather common on the under side of rocks at Coney Island. All of those seen were blue. A very large specimen of *Linckia guildingii* was found under the bridge at Coney Island. It had only four arms, and one of these was broken, but the perfect arms measured 20 cm. long, and 7 cm. in circumference.

No echinoids except *Toxopneustes* were found by me, but that species is very abundant almost everywhere. Brittle-stars are abundant, particularly *Ophionereis reticulata*, which may be found anywhere in the sand. *Ophiura appressa* was found rather common near Coney Island, and *Ophiocoma echinata* was common at the same place and elsewhere. A single small specimen of *Ophiocoma pumila* with six arms was collected under the bridge at Coney Island, and in the same locality a very small, six-armed *Ophiactis* was found, which I refer with some hesitation to *mülleri* Ltk. The colors are bright green and white, and the specimen agrees exactly in this and some other particulars with *O. savignyi* Ljn.; but as *mülleri* has been recorded previously from Bermuda, it seems best to refer my specimen to that form. The most interesting ophiuroid seen was *Ophiomyxa flaccida*, of which a number of specimens were collected under the bridge near Coney Island, in three feet of water. The largest measured 26 mm. across the disc, and the arms were 130 mm. long. The color varies most remarkably. Two specimens were uniform tawny orange; others were olive-green, the arms banded with darker; one was yellowish green; and several had the olive-green disc crossed and marked with dirty white. These colors are pretty well kept in both alcoholic and dried material. This species was previously known from Bermuda from a single specimen, so that its occurrence in some numbers is of no little interest. It is a very active animal, and makes its way about among the broken slabs of rock with great rapidity. The arms are so brittle that it is difficult to capture an uninjured specimen.

During my visit in April, specimens were obtained of all the holothurians previously recorded from Bermuda, except *Synapta inhaerens*. *Synapta acanthia* was found only at the cove in Coney Island, and is not abundant there. It is so much larger than *inhaerens* that it is hard to get perfect specimens, as it lives deep in the sand and is easily broken. The best specimen I secured was about 35 cm. long, but it broke up into several pieces soon after being placed in a bucket. In its habits this species seems to resemble *inhaerens* quite closely. A number of specimens of *S. vivipara* were collected in the bright green seaweed (*Ulva*) in Bailey's Bay. They were all green in color, somewhat marked with white. In Jamaica where the same species lives in a reddish brown seaweed (*Acanthophora*) the ground color is reddish brown, though there is often much green pigment in the skin. The difference in color makes the appearance of Bermudan specimens very different from that of those from Jamaica. I think there can be no doubt that *Synapta pourtalesii* of Selenka is this species. A careful reading of Pourtales' description, and the study of the living animals, has convinced me that the form which he described from Biscayne Bay, Florida, as *S. viridis* (= *pourtalesii* Sel.) is identical with the *Synaptula vivipara* of Oerstedt, described nearly two years earlier. The species has therefore a wide range, having been recorded from Bermuda, Florida, Central America, Jamaica and Brazil. The commonest synaptid in Bermuda is *Synapta roseola* (Ver.), though *Chiridota rotifera* Pourt. is very common. These two species were found almost everywhere under stones between high and low water mark and in shallow water. They are constantly associated, and are abundant in Bailey's Bay and around Coney Island and occur all along the north shore. The *Chiridota* grows to a much larger size than has been known hitherto, for specimens 6 or 7 cm. long were common and one specimen 10 cm. long was collected. Many contained young in the body-cavity, indicating that the species is viviparous in Bermuda as it is elsewhere. In the collections made by Mr. Carpenter there are specimens of *S. vivipara* and *C. rotifera*. Of the former, Mr. Carpenter says: "We found it in abundance in "sea-lettuce" and another seaweed along the Paget shore in Hamilton Harbor. Color of most a reddish brown, streaked transversely with white. Others of a greenish brown color, also streaked with white." The absence of *S. inhaerens* from both Mr. Carpenter's collections and mine is noticeable. *Roseola* is so abundant that it seems strange that *inhaerens* should

be so rare. The specimens of *roseola* from Bermuda agree exactly with those from Wood's Hole, Massachusetts, and confirm the diagnosis of that species which has recently been published.

Of the other holothurians I found *Stichopus möbii* the most abundant, occurring literally by thousands. *Holothuria captiva* and *surinamensis* are both very common in suitable places under rocks in shallow water. The former, when disturbed or irritated sufficiently, always ejects its pure white and very viscid Cuvier's organs. *Cucumaria punctata* is not very common, but occurs under rocks with the two preceding species. A number of specimens were collected near Coney Island. They differed somewhat in color, one individual having the pedicels a distinct red. I took especial pains to investigate the relation of *Stichopus diaboli* and *xanthomela* of Heilprin. The very first stichopus found could not be referred to either species, as it was of a uniform reddish brown color without a spot! Other specimens were subsequently found which showed a very evident intergradation in color between the uniformly black individuals and the spotted ones. Two specially noteworthy specimens were collected in Harrington Sound; one was uniformly dark brown but showed faintly large blotches of a darker color; the other was reddish brown above, but so thickly blotched with black that the ground color appeared only as two longitudinal bands, while underneath it was almost black with a very narrow longitudinal white stripe along each side. On asking the boatman, an intelligent native, if there were two kinds of "sea-puddings," as he called them, he replied: "Oh, no, the spotted ones are the young of the other." One fact seems to count against this view. I could find no *small* spotted ones; all of the specimens found, less than six inches long, were uniformly dark brown or black. If the color difference is not a question of age, it is hard to explain it unless we call it simply "individual variation." I cannot believe, however, that it indicates any specific difference. Mr. Carpenter writes me: "I regret that the large size of the holothurians made it impracticable to bring back a complete series showing gradation stages, as far as color is concerned, between Professor Heilprin's *Stichopus xanthomela* and *Stichopus diaboli*. I am inclined to think that such a series could be obtained. We have some half-dozen specimens which show marked variations in the relative amounts of reddish yellow and black."

In the genus *Stichopus* the number, size and arrangement of the papillae and tubercles is extremely variable, many specimens being

almost smooth with a row of small tubercles along each side, while others are extremely rough and warty; and all conditions between the two extremes could be found, nor is any particular condition correlated with any particular color pattern. The more individuals of the Bermudan species I examined, the more I became convinced that specific differences in this genus based on the size, number or arrangement of pedicels, papillae, or tentacles, or on the color, are worthless. The most reliable characters are to be found in the calcareous parts, while the general size and shape and the habits will assist in specific determination. Until some new evidence is introduced, I must regard *diaboli* and *xanthomela* as one species, and both names as synonyms of *möbii* Semp.

The collection which Mr. Carpenter sent me contains several specimens of a holothurian not previously reported from Bermuda. They were collected in Hungry Bay on the south shore, June 26, 1899. The notes with them read: "Found under stones on sandy bottom in a foot or so of water. Specimens have a ground color of brown and drab in several shades, with more or less numerous blotches of steel-blue. Body usually tapering toward the two ends. Length $4\frac{1}{2}$ –8 inches; greatest diameter $\frac{7}{8}$ – $1\frac{1}{4}$ inches." The alcoholic specimens are very strongly tinged with dark yellow, and the steel-blue has become purplish. These specimens represent a species originally described from Brazil by Mr. Richard Rathbun, to which he gave no name but which Lampert, in 1885, called *Holothuria rathbuni*. The species occurs in Puerto Rico and is common in Jamaica, and my specimens from the latter island agree perfectly with these from Bermuda.

The observations made during 1899 make some corrections necessary in statements made last year (Further notes on the echinoderms of Bermuda — *Annals N. Y. acad. sci.*, vol. 12, no. 7, July 7, 1899) regarding the abundance and distribution of certain forms. Moreover, there are two changes to be made in the list of holothurians; so a corrected list of the echinoderms of Bermuda is appended, with a statement of their abundance and the localities where they have been collected.

ASTEROIDEA.

1. *Luidia clathrata* (Say). Not uncommon. Hamilton Harbor. Harrington Sound.

2. *Asterina folium* (Ltk.). Common. Coney Island, Castle Harbor, etc.
3. *Linckia guildingii* (Gray). Not common. Coney Island.
4. *Asterias tenuispina* Lamk. Common. Harrington Sound. Flatts. Coney Island.

OPHIUROIDEA.

5. *Ophiura appressa* Say. Not uncommon. North shore.
6. *Ophiactis mülleri* Ltk. Rare. North shore. Coney Island.
7. *Ophionereis reticulata* (Say). Abundant everywhere.
8. *Ophiostigma isacantha* (Say). Rare. North shore.
9. *Ophiocoma echinata* (Lamk.). Common. North shore. Harrington Sound.
10. *Ophiocoma pumila* Ltk. Not common. Castle Harbor. Bailey's Bay.
11. *Ophiomyza flaccida* (Say). Not uncommon. Coney Island.

ECHINOIDEA.

12. *Cidaris tribuloides* (Lamk.). Not found along shore. Common at North Rock.
13. *Diadema setosum* Gray. Common about the reefs.
14. *Echinometra subangularis* (Leske). Common. Everywhere.
15. *Toxopneustes variegatus* (Lamk.). Abundant everywhere.
16. *Hipponoë esculenta* (Leske). Not common. Reefs along north shore.
17. *Mellita sexforis* A. Ag. Not common. Flatts.
18. *Echinoneus semilunaris* (Gmel.). Apparently quite rare. Has not been collected recently. Locality unknown.
19. *Brissus unicolor* (Kl.). Apparently rare. Not recently collected. Locality unknown.

HOLOTHURIOIDEA.

20. *Cucumaria punctata* Ludw. Not abundant. North shore.
21. *Holothuria captiva* Ludw. Quite common. North shore.
22. *Holothuria surinamensis* Ludw. Abundant. North shore.

23. *Holothuria rathbuni* Lamp. Not common. Hungry Bay.
24. *Stichopus möbii* Semp. Very abundant. Harrington Sound. Castle Harbor. Hamilton Harbor. North shore.
25. *Synapta acanthia* Clark. Not common. Coney Island.
26. *Synapta inhaerens* (O. F. Müll.). Apparently quite rare. Coney Island.
27. *Synapta roseola* (Verr.). Abundant. Everywhere.
28. *Synapta vivipara* (Oerst.). Common. Bailey's Bay. Coney Island. Hamilton Harbor.
29. *Chiridota rotifera* (Pourt.). Abundant. Everywhere.

NOTE.— Since the above list was prepared, Professor A. E. Verrill, of Yale University, has published an account of the echinoderms collected by his party in 1898 (Trans. Connecticut acad. arts and sci., 1900). His list includes a large number of ophiuroids, not previously met with, but there are no additions to the other classes.

OLIVET COLLEGE, MICHIGAN,
FEBRUARY 27, 1900.

Printed, May, 1901.

No. 17. — *Proceedings of the Annual Meeting, May 1, 1901.*

REPORT OF THE CURATOR, MAY 1, 1901.

THE most important event to be chronicled for the past year is the reception of the Gurdon Saltonstall fund. This was given by the will of Henry Saltonstall, who bequeathed fifteen thousand dollars to this Society a number of years ago in a will, dated 1891, which went into effect after his death in 1894. This was increased by ten thousand dollars through the will of his wife, who died quite recently in 1901. The terms of these joint gifts are the same, and the reasons given by Mr. Saltonstall are particularly pleasing. His words are, "to the Boston Society of Natural History as a memorial of my (said) son and in gratitude for the benefit and pleasure derived by him from his association with the (said) Society." Such donations are absolutely essential to our continued existence, but they have been so few and far between, with the exception of the last two years, that we have suffered and must continue to suffer from the want of an adequate income to carry any of our plans to completion. Although we have the necessary collections, we are still as much in need of funds for the installation of a proper exhibition of New England natural history, a thing that does not exist in this region or any other, as we were two years ago. The teaching of the visitors to the Museum, an equally unique scheme that has been shown to be practicable by Dr. Grabau and others, has lately been abandoned because no funds existed to pay a teacher. The exposition of the natural history, topography, and geology of the region immediately around us which we call the Boston Basin would do more towards advancing the proper teaching of natural history in this region than any one movement that could be made, but this also cannot be completed for similar reasons.

We have also received from Mr. Walter Hunnewell a gift of two thousand dollars "in memory of his son, Willard P. Hunnewell." This and Mr. and Mrs. Saltonstall's gifts show conclusively, that the free policy of this Society in welcoming young people to all the advantages it has to offer may have material returns not contemplated by the believers in this mode of working.

It is sometimes the duty of the Curator to recall the attention of the Society to the loss of some prominent member and this year it is the sudden death of Mr. Augustus Lowell. In spite of his advanced age, this decease came with a shock to most of the older members on account of his extraordinary activity and appearance of good health. Mr. Lowell was elected to this Society in 1860, and at the time of his decease had been an active member for forty years. During part of this time he served in company with his father, John A. Lowell, and afterwards followed with relation to this Society the same benevolent policy as had his father, to whose generosity we owe the courses of lectures given in this room in 1870-71 and also the Lowell Herbarium. Mr. Augustus Lowell began to support the larger part of the annual work of the Teachers' School of Science in 1882 and continued this patronage until the year of his death. The school dates its greatest usefulness and stability from this year (1882), and it is likely that it would not have been able to survive in the face of the indifference of most of the masters of the public school and of the School Board had it not been for the assistance of the Trustee of the Lowell Fund. Its operations outside of the Lowell Free Courses, with the exception of Professor Barton's field courses given in the last three years, have not been, comparatively speaking, very extensive or for the most part remunerative to the lecturers. Mr. Lowell was also, although not a constant attendant at our Council meetings, always ready to serve this Society when there was any real need of his assistance. The Curator, who has been more or less employed by the Trustee of the Lowell Fund for many years, feels that this notice would be inadequate if he did not express a sense of his personal obligations to this gentleman for courteous treatment and appreciative consideration of his work that has made connection with the Lowell Institute a pleasure independent of all pecuniary returns.

The School has also lost by sudden death one of its strongest supporters in Dr. Robert W. Greenleaf. This gentleman for about eight years, from 1891 to 1899, was the most successful laboratory teacher of botany that it has ever had. Dr. Greenleaf was still a young man, and his loss is deeply felt by his many friends and former pupils.

MINERALOGY AND GEOLOGY.

Professor Crosby reports as follows: During the early part of last summer the printing of Part 3 of the Geology of the Boston Basin was finally completed. During the remainder of the year he has been at work on Part 4 which embraces the Neponset Valley and the belt of islands extending from the mouth of the Neponset River in an east-northeast direction through Boston Harbor to Boston light and the outer Brewster. This well-defined linear group of islands lies exactly in the axis of the Neponset River and may be regarded as a continuation, geologically, of that valley. It has, therefore, seemed appropriate to designate these collectively "the Neponset islands." The field work for Part 4 is completed, except as there will be occasion to review special points in describing and discussing previous observations; and except also the attention that must be periodically given to the exposures of rocks made in the tunnels now being driven in making the high level sewer through the Neponset Valley. This work affords fresh and continuous sections of the rocks that should not be neglected. The heartiest cooperation has been given by the engineers; and during the year Professor Crosby has prepared a report on the geology of the tunnels for Mr. W. M. Brown, Chief Engineer of the Metropolitan Sewerage Commission, and this has been printed as a part of that gentleman's annual report.

Miss Bascom, professor of geology at Bryn Mawr, who has already made and published a petrographic study of the volcanic rocks of the Neponset Valley, is, at Professor Crosby's request, now investigating also the plutonic and dike rocks which have unexpectedly developed many points of special petrographic and structural interest. Professor Crosby's new colleague at the Institute, Dr. C. H. Warren, who is a skilful petrographer, has also assisted him materially. A year ago Mr. M. L. Fuller undertook, at Professor Crosby's suggestion, a detailed study of the glacial lake of the upper Neponset Valley, similar to Dr. Grabau's study of Lake Bouvé. This part of the work was interrupted when Mr. Fuller accepted a position on the U. S. Geological Survey; but he has now given in a very carefully prepared report on the important part that he has completed, and he expects this summer to be able to finish the whole of the chapter of Part 5 that had been assigned to him.

Mr. T. A. Watson's cordial interest in this work continues unabated, and we have additional reasons for being grateful to this gentleman for his appreciation of this investigation. Mr. John L. Gardner, Jr., has also manifested a special interest and has kindly offered to obtain for Professor Crosby all the photographs that may be needful for illustration and study.

The additions to the mineral collection during the past year have been more important than usual. These include, first, a series of exceptionally attractive and desirable specimens obtained by exchange. In this way more than \$100 worth of desiderata have been added to our collection without any expense to the Society.

Mr. Gardner has also given us from his private collection a valuable series of minerals.

We were also able to obtain from the Waterston collection a number of desirable specimens and more might have been selected but for the fact that no localities were given on the labels.

All the accessions of the year have been incorporated in the collection and properly mounted and labeled; and this and the geological collection are in good condition.

The specimens illustrating Part 3 of the Boston Basin geology have been added to the permanent series and properly labeled, but it is greatly to be regretted that for lack of room this material and the maps and sections supplementing the collection cannot be effectively exhibited. Professor Crosby collected in Colorado and Missouri an exceptionally complete series of the ores and minerals of the Joplin zinc district, and all of these that were desirable for exhibition were donated by him to the Society.

DYNAMICAL ZOOLOGY.

Miss Bryant has picked out a series of the different varieties of pigeons to illustrate Darwin's observations upon the descent of these from the rock pigeon, *Columba livia*, and more or less work has been done in other directions.

SYNOPTIC ZOOLOGY.

Mrs. Sheldon still continues her work in this department, of which a general notice was given in the last annual report. She

has this year spent the larger part of her time upon fourteen of the orders of insects, and Miss Martin during her enforced absence has been employed by Mrs. Sheldon, free of expense to the Society, in making drawings of this group for exhibition in the Synoptic collection. About 160 figures have been added to the collection in this way and some two hundred more have been selected and studied by Mrs. Sheldon, who has also revised and rewritten about two hundred and fifty pages of text, added about thirty-one specimens to those on exhibition, and made lists of specimens desired to fill our blanks. Unfortunately a considerable proportion of these are not procurable, but all that are available will be obtained without expense to the Society. Miss Bryant has assisted Mrs. Sheldon by mounting and labeling a number of specimens.

BOTANY.

Miss Carter reports that during the past year the systematic arrangement of the Society's duplicates has been completed. The collections in the exhibition cases have received their annual summer cleaning. The accessions to the herbarium (245 specimens) have been mounted and duly incorporated in the collections.

A thorough revision of the entire herbarium has been undertaken, made necessary by the many changes of the past twenty years. Thus far the following 18 orders have been finished: Ranunculaceae, Dilleniaceae, Calycanthaceae, Magnoliaceae, Anonaceae, Menispermaceae, Berberidaceae, Nymphaeaceae, Sarraceniaceae, Papaveraceae, Cruciferae, Capparideae, Resedaceae, Cistineae, Violaceae, Bixineae, Pittosporae, and Polygalaceae.

The following accessions are hereby acknowledged: 243 specimens mostly from California and Colorado from Miss Grace G. Cowing. A fine specimen of *Arceuthobium pusillum* from Maine, through Mrs. L. P. Jenney; also a Vermont specimen of the same plant from Prof. L. R. Jones.

Seventeen persons have been allowed the special use of the herbarium, under the supervision of the assistant.

PALEONTOLOGY.

Miss Bryant has spent considerable time in removing faded labels and identifying and labeling fossils. A small collection of fossils

donated by Miss Isabel L. Johnson and another from Mr. A. W. Grabau have been properly labeled. The European collection of fossils has been all looked over and specimens dusted. A number of fine corals have been purchased from G. K. Greene, and these have been labeled and catalogued; also a few Solenhofen fossils received from Mr. J. L. Gardner. The New England fossil collection made by Mr. Grabau has been labeled.

MOLLUSCA.

Miss Martin did some work, before leave of absence was granted her, upon the collections of duplicate shells in giving generic names to the various lots. Mr. Sornborger completed this work by picking out and packing ten sets. These were generically identified and consisted of from 26 to 93 genera.

Miss Bryant has arranged systematically and labeled the New England collection of Mollusca. The same assistant has completed the cataloguing of the Cyrenidae, the most valuable part of the Roper collection. This has finished the cataloguing of this large collection, received in 1899, except the Unionidae. When these are completed a final report will be made.

The Curator has been prevented partly by other duties, and partly by the growth of the work itself, from completing the manuscript of the ground shells of Achatinellidae, but the work has been going on steadily and the detailed descriptions of species have been in large part completed. The greatest difficulty has been removed by a pecuniary grant from the Bache Fund, under the charge of the National Academy of Science. This has enabled the Curator to employ an assistant to do the work of measuring the shells. The points aimed at are as follows: to determine the relations of the average size of species to their positions or grades in their natural genetic series, their relations to the area of the islands upon which they live, whether there is a normal size or range of dimensions in each species, and so on.

INSECTA AND ARACHNIDA.

Mr. Samuel Henshaw reports that he has revised the series of New England insects throughout seven families of Orthoptera, one

of Coleoptera, four of Lepidoptera Heterocera, and six of Lepidoptera Rhopalocera according to the list given below.

The following table shows the condition of the series of New England insects on exhibition, as revised : —

		Number of species credited to New England.	Number of species in collection.	Number of speci- mens in collection.
Orthoptera :	Forficulidae.	3	2	6
	Blattidae.	12	7	7
	Mantidae.	1	1	1
	Phasmidae.	1	1	1
	Acridiidae.	50	37	63
	Locustidae.	23	16	27
	Gryllidae.	18	11	20
Coleoptera :	Cicindelidae.	21	19	32
Lepidoptera Heterocera :	Citheroniidae.	6	1	1
	Hemileucidae.	1	1	2
	Saturniidae.	8	7	16
	Sphingidae.	46	21	25
Lepidoptera Rhopalocera :	Hesperidae.	40	19	28
	Papilionidae.	6	5	9
	Pieridae.	11	5	8
	Lycaenidae.	20	14	24
	Nymphalidae.	32	26	78
	Satyridae.	7	7	21

A number of very acceptable New England Lepidoptera have been given by Miss C. G. Soule and Mr. A. P. Morse. A specimen of trap-door spider with two nests was also received from Miss S. Minns.

SPONGES.

Mrs. Hammatt has begun work on the Curator's collection of New England sponges. This is an extensive collection of these animals, mostly in alcohol, and it is hoped that this lady will be able to work up these materials.

BIRDS AND MAMMALS.

Mr. Batchelder reports having done some work on the New England collection of birds, in labeling and arranging them, and a further

instalment has been received of the Nuttall Ornithological Club's collection of New England birds' nests and eggs. Part of this has been mounted and placed in the cases.

Mr. Sornborger has been employed for the largest part of his time upon these collections. All of the birds and mammals have been carefully examined, and a number of infected specimens having been found, they were all cleaned and disinfected. All the exhibition cases also have been more thoroughly examined than usual. Unfortunately a leak in the roof above Gallery Q occurred and made the cases in that gallery damp, and before it was discovered, occasioned some damage to the mounted birds through the growth of mould. These birds have all been cleaned and will be restored to their cases as soon as the walls and shelving have been painted. Mr. Sornborger has also done considerable work upon the birds received from the Boston Museum. The supposed Wilson types discovered by Mr. Maynard and purchased by Mr. William Brewster have been most generously restored to our Museum by the latter.

LABORATORY.

The room in our basement has been used as in previous years by the classes of the Boston University and the Teachers' School of Science. A number of new diagrams have been made by Miss Martin.

The Museum has been visited on closed days, when special permission is necessary, by 199 pupils representing seven schools, a large decrease from last year and the year preceding. It is known, however, that some classes with their teachers visit the Museum on public days, when no record of their numbers can be obtained.

TEACHERS' SCHOOL OF SCIENCE.

The class in field geology from the Boston Normal School was carried on last year, 1900, as usual, with twenty-one members. This year, 1901, it was considered no longer advisable by authorities of the School to accept free instruction, although Professor Barton was willing to continue his annual donation. No funds were obtainable, however, to pay an instructor and none were offered by the

authorities, and the course was consequently discontinued. It is obvious that this is the right stand for the school to take, but it is also evident that the members of this class have been deprived of an important part of their preparation as teachers.

The course of field lessons for teachers during the spring has been continued by the same generous donor as during the preceding year. These consisted of ten lessons given on Saturdays from April 21 to June 23 inclusive. The total number attending this course was 165. Average attendance for the term was 37.9. The autumn course of field lessons also consisted of ten in number, from September 15 to November 17 inclusive. The attendance was as follows: Greatest number present at one time, 88; least number present at one time, 21, a stormy day; average for the term, 60.6; average for the term, not counting the stormy day, 65. The field lessons in general were given at localities not far distant from Boston and occupied a half day. A few were given at greater distances and occupied from one to three days.

In the spring course, taking advantage of the holiday given Boston teachers on June 17, a trip of three days in length was made to the Connecticut Valley. Through the kindness of the management of the Boston and Maine R. R., there was a special reserved car for the party, and on their arrival at Holyoke, they were met at the railway station by Mr. Loomis, president of the Holyoke street railroad, who provided two special electric cars for their accommodation, and this gentleman personally accompanied the party to the top of Mt. Tom and spent the afternoon there with them. They were also joined at Holyoke by a large delegation from the Geological Club of Springfield under the leadership of Mr. William Orr of the Springfield High School. Prof. B. K. Emerson, of Amherst College, who is the special authority for this region, kindly gave his services to the class for the afternoon, and the members consequently had exceptional opportunities for learning the structure of this exceptionally interesting region. Monday was spent at Amherst College and vicinity, where the class again had the valuable services of Professor Emerson, who gave an extended description of the collection of footprints and then a general lecture, supplemented by maps and sections, in which the geologic history of the Connecticut Valley was given.

Taking advantage of the very cheap rates furnished by the Boston and Maine R. R., a two days' trip was made in the autumn to North Adams. Through the courtesy of the railway officials, the class

traveled in two reserved cars. Each member of the class was provided with a printed description of the various geological and geographical features that can be seen on the way. At North Adams barges were in waiting which at once took the party over the Hoosac Mountain range, giving them a chance to study its structure, and to visit the eastern portal of the Hoosac Tunnel. During the evening Mr. Murdock, principal of the State Normal School, kindly gave the class an exhibition of that building and the use of its large lecture room and stereopticon. By this means Professor Barton gave the class an illustrated lecture upon what had been seen during the day and upon the general geological formation and history of Northwestern Massachusetts. The next day was spent in a visit to the top of Mt. Greylock, in a study of its structure and its relations to the surrounding region.

The field course has begun this spring with an attendance of about forty.

BAYVILLE SUMMER COURSES.

A series of courses in natural history was given at Bayville, Lincoln Bay, Maine, beginning Friday, July 6, 1900, and continuing for three weeks. The following is an outline of the subjects that were studied:—

Geology was given by Mr. A. W. Grabau. The elements of physical geography, geology, and mineralogy were taught, chiefly by field excursions. A study of two small rocky islands was undertaken, and topographic and geological maps were prepared by the students. A relief model of the smaller of the two islands was made by the students.

Zoology was conducted by Mr. Freeland Howe, Jr. In this course the habits and structure of representative types of animals were studied, especially the littoral forms, and besides the laboratory work, observation lessons in the field were also given by the instructor.

Botany was conducted by Mr. C. E. Preston. Common plants were studied and special attention was given to the methods of plant analysis and dissection. Considerable attention was given to the common trees of the region, and the relation of plants to their environment was considered.

The work consisted of two hours a day upon each of the three subjects and excursions and laboratory exercises. Dredging, collecting, and the use of tow-nets, and even methods of preservation and mounting were taught to a limited extent.

In addition to the regular courses, three evening lectures were given. The following were the subjects: Air and life, by Mr. Howe; Plants and their natural surroundings, by Mr. Preston; Scenery of the New England coast, by Mr. Grabau. These lectures were open to the public and were well attended.

The total number of students who registered was 17.

WOODS HOLL EXCURSION.

A three days' excursion to Woods Holl was made in June under the guidance of Mr. A. W. Grabau. The party consisted of 11 persons. They left Boston Friday afternoon, June 15, returning Monday afternoon, June 18. As on previous excursions of this kind, a study of the invertebrate fauna of the region was undertaken, the lessons being a continuation of those given in this locality in previous years.

LOWELL FREE COURSES.

A course on structural geology of fifteen lessons of two hours each was given by Prof. Geo. H. Barton in the lecture room of the Society during the past winter. This was the third series in a four years' course. The instruction was given by means of lectures, illustrated by diagrams, charts, and a large number of specimens both for class and table use. The stereopticon was also used whenever good illustrations of the subject in hand were to be obtained. Examinations as usual were an essential part of the work, one of twenty minutes' length being held at each exercise; and a final examination of three hours was held at the close of the term. The average rank in these examinations was high and shows an extreme interest in the work when it is recognized that this is carried on in the spare time of the teachers who are also heavily burdened with the necessary work of the week in school. The average attendance for the term was 99.1.

The botany of the Lowell Free Courses was conducted by Mr. B. H. Van Vleck and in continuation of that taken up last year; namely, the study of a limited number of representative forms with special reference to the more important structural and physiological questions. Fifteen lessons of two hours each were given. The work this year was confined almost entirely to the Fungi. An abundance of material had been provided, chiefly for use with the microscope. About 30 persons have been members of the class, and of these, 20 were quite regular in their attendance. Ten of these presented themselves for examination and all passed.

The first year of a five years' course on elementary zoology, consisting of seventeen lessons of two hours each, was given by the Curator, beginning Oct. 20, 1900, and ending March 17, 1901. There were fifty tickets issued and the average attendance was twenty-five, but out of this number only nine presented themselves for examination. This was due to the fact that a considerable number of those in constant attendance were old pupils who had already been through the last five years' course and had graduated. Seventeen lessons of mixed lecture and laboratory work of two hours each were given, illustrated as usual by specimens and diagrams.

REPORT OF THE SECRETARY AND LIBRARIAN, CHARLES F. BATCHELDER.

MEMBERSHIP.

During the year 1900-1901 one Honorary Member, Franz Leydig, and two Corresponding Members, E. L. Bouvier and A. Smith Woodward, have been added to the Society. Forty-eight Corporate Members have been elected. Eleven Corporate Members have become Life Members.

Two Corresponding Members have died during the year — George Augustus Boardman and Christian Frederik Lütken. From its Corporate Membership the Society this year has lost by death men of much importance in the community. Ten Corporate Members have died — Edward C. Cabot, Thomas Gaffield, Robert W. Green-

leaf, John E. Hudson, Willard P. Hunnewell, Augustus Lowell, William Minot, Barthold Schlesinger, Augustine Shurtleff, and Roger Wolcott. Eight Corporate Members have resigned, and eight have been dropped from membership for non-payment of dues.

The membership of the Society, May 1, 1901, consists of ten Honorary, 128 Corresponding, and 449 Corporate Members. There are 16 Patrons. The Corporate Membership is now larger than in any previous year.

The Corporate Members elected during the year, and the dates of their election, are as follows:—

Glover M. Allen, April 16, 1901.
 Edward M. Brewer, Feb. 27, 1901.
 J. Henry Brooks, April 16, 1901.
 Samuel N. Brown, April 16, 1901.
 John A. Burnham, Dec. 19, 1900.
 Eliot C. Clarke, Dec. 19, 1900.
 John T. Coolidge, Dec. 19, 1900.
 Allen Curtis, Dec. 19, 1900.
 George B. Dorr, Dec. 19, 1900.
 Charles Lincoln Edwards, Dec. 19, 1900.
 Dudley B. Fay, Dec. 19, 1900.
 Miss Sarah B. Fay, Dec. 19, 1900.
 L. Carteret Fenno, Dec. 19, 1900.
 Francis B. Forbes, Dec. 19, 1900.
 Frank H. Foster, April 16, 1901.
 Mrs. Caroline S. Freeman, Feb. 27, 1901.
 Miss Ellen Frothingham, Dec. 19, 1900.
 Henry S. Grew, April 16, 1901.
 C. Judson Herrick, Dec. 19, 1900.
 Oliver H. Howe, Dec. 19, 1900.
 Charles W. Hubbard, Dec. 19, 1900.
 Mrs. Clara Carter Hyatt, Feb. 27, 1901.
 Miss Marian C. Jackson, Dec. 19, 1900.
 George F. Jelly, Dec. 19, 1900.
 H. S. Jennings, April 16, 1901.
 Mrs. M. M. Kehew, Dec. 19, 1900.
 Andrew J. Lloyd, Dec. 19, 1900.
 F. B. Lund, Feb. 27, 1901.
 John W. McKim, Dec. 19, 1900.
 Mrs. Lucy F. Minot, Dec. 19, 1900.

Robert S. Minot, Feb. 27, 1901.
 Robert W. Morville, Jr., Dec. 19, 1900.
 James G. Needham, Dec. 19, 1900.
 Mrs. Henrietta Page, Feb. 27, 1901.
 Charles J. Paine, Dec. 19, 1900.
 Mrs. L. A. Peabody, Dec. 19, 1900.
 Henry Pickering, Dec. 19, 1900.
 Wallace L. Pierce, Dec. 19, 1900.
 Alfred Emerson Preble, Dec. 19, 1900.
 Nathan B. Prescott, Dec. 19, 1900.
 T. E. Proctor, April 16, 1901.
 George H. Shull, Dec. 19, 1900.
 Jewell D. Sornborger, April 16, 1901.
 F. P. Sprague, Dec. 19, 1900.
 Myles Standish, Dec. 19, 1900.
 William Lyman Underwood, Dec. 19, 1900.
 Charles Hyde Warren, Dec. 19, 1900.
 Willis R. Whitney, Feb. 27, 1901.

MEETINGS.

Fourteen regular meetings of the Society have been held during the year. The number of persons present has varied from twelve to ninety-eight, the average being over forty-one.

Fifteen formal communications have been made at the meetings by fourteen persons. Five of these persons have not previously spoken before the Society. Four papers have been presented by title.

The meetings, attendance, and communications have been as follows:—

May 2, 1900. Annual meeting. Forty-seven persons present.

Reports of the Curator, Secretary, Librarian, Treasurer, and Trustees.

Prof. F. W. Putnam. Prehistoric ruins of the Chaco Cañon and the cliff houses of the Mancos Cañon.

May 16, 1900. General meeting. Fifty-one persons present.

Dr. Edward G. Gardiner. Porto Rico.

November 7, 1900. General meeting. Twenty-nine persons present.

Dr. A. W. Grabau. The development of the bi-serial arms in certain crinoids.

Mr. J. H. Emerton. Animal tracks in the sand.

Dr. Thomas Dwight. Description of the human spines showing numerical variation in the Warren Museum of the Harvard Medical School. (By title.)

November 21, 1900. General meeting. Eighty persons present.

Dr. Thomas S. Roberts. The nesting habits of Franklin's Gull in Minnesota.

December 5, 1900. General meeting. Twenty-four persons present.

Major William J. Davis. Fossil corals of Kentucky.

December 19, 1900. General meeting. Eighteen persons present.

Dr. Thomas Dwight. Numerical variation in the human spine.

January 2, 1901. General meeting. Forty-seven persons present.

Prof. Alpheus Hyatt. A new law of evolution.

January 16, 1901. General meeting. Thirty-six persons present.

Prof. Robert DeC. Ward. The international cloud classification.

Messrs. Gerrit S. Miller, Jr., and James A. G. Rehn. Systematic results of the study of North American land mammals to the end of the year 1900. (By title.)

February 6, 1901. General meeting. Twenty-seven persons present.

Prof. J. S. Kingsley. Origin of the Mammalia.

February 20, 1901. General meeting. Ninety-eight persons present.

Prof. William Morris Davis. The Grand Cañon district of Arizona: a technical geological discussion.

March 6, 1901. General meeting. Thirty-five persons present.

Mr. Samuel C. Prescott. On the applications of bacteriology to certain arts and industries.

Prof. Hubert Lyman Clark. Echinoderms from Puget Sound. Observations made on the echinoderms collected by the parties from Columbia University, in Puget Sound in 1896 and 1897. (By title.)

Prof. Hubert Lyman Clark. Bermudan echinoderms. A report on observations and collections made in 1899. (By title.)

March 20, 1901. General meeting. Forty-seven persons present.

Mr. J. H. Emerton. The cobweb spiders, with photographs of their webs.

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April 8, 1901. General meeting. Twelve persons present.

Prof. J. E. Wolff. The extinct volcanoes of the Puy de Dôme region and the Mt. Dore, Auvergne, France.

April 17, 1901. General meeting. Twenty-five persons present.

Mr. Robert M. Yerkes. Animal psychology: aims, methods, and present tendencies in the study of the mental life of animals.

PUBLICATIONS.

During the year the following publications have been issued:—

The anatomy and development of *Cassiopea xamachana*. By Robert Payne Bigelow. Memoirs, vol. 5, no. 6, 46 pp., 8 pls., 12 cuts.

Description of the human spines showing numerical variation in the Warren Museum of the Harvard Medical School. By Thomas Dwight, M. D., LL. D. Memoirs, vol. 5, no. 7, 76 pp., 23 cuts.

Proceedings of the annual meeting, May 2, 1900. Proceedings, vol. 29, no. 12, 18 pp.

The embryonic history of imaginal discs in *Melophagus ovinus* L., together with an account of the earlier stages in the development of the insect. By H. S. Pratt, Ph.D. Proceedings, vol. 29, no. 13, 32 pp., 7 pls., 5 cuts.

Glacial erosion in France, Switzerland, and Norway. By William Morris Davis. Proceedings, vol. 29, no. 14, 50 pp., 3 pls., 7 cuts.

Geology of the Boston Basin. Part III. — The Blue Hills Complex. By William O. Crosby. With supplementary chapters by A. W. Grabau. Occasional Papers, vol. 4, part 3, 406 pp., 24 pls., 2 maps, 25 cuts.

LIBRARY.

The additions to the library during the year have been:—

	8vo.	4to.	Folio.	Total.
Volumes	292	62	4	358
Parts	1,914	424	2	2,340
Pamphlets	399	33	10	442
Maps			34	34
Total	2605	519	50	3174

The library now contains 26,300 volumes, 1411 current or otherwise incomplete volumes, and 13,753 pamphlets.

New exchanges have been established with the Maryland Geological Survey, the Chicago Entomological Society, the Société Scientifique de Chevtchenko a Lemberg, and the Tiflis Botanical Garden.

One exchange has ceased. The Society now exchanges with 438 institutions and periodicals.

Eight hundred and eighty-five books have been borrowed by 111 persons; 536 have been borrowed for use in the building. The library has been consulted about 280 times.

Four hundred and twenty-one volumes have been bound in 357 covers.

The following serials have been indexed: Transactions of the Linnaean Society of New York, two volumes; Mémoires de la Société des Sciences Naturelles de Neuchâtel, four volumes; Proceedings of the United States National Museum, ten volumes; Journal de zoologie, six volumes; Proceedings of the Boston Society of Natural History, twenty-eight volumes. Current volumes of serials already indexed, are indexed as received.

WALKER PRIZES.

The subject appointed for competition in 1901 was a monograph on any problem connected with or any group belonging to the North American fauna or flora.

The following awards have been reported by the Committee: a prize of sixty dollars for an essay entitled, "The Cytogeny of *Podarke obscura*," by Aaron L. Treadwell.

A prize of fifty dollars for an essay on *Liriodendron*, by Edward W. Berry.

The subjects for competition in 1902 are: —

1. Nuclear fusions in plants.
2. The fate of specific areas of the germ of chordates, as determined by local destruction.
3. The reactions of organisms to solutions, considered from the standpoint of the chemical theory of dissociation.

REPORT OF THE TREASURER, EDWARD T. BOUVÉ.

ANNUAL STATEMENT, MAY 1, 1901.

To cash received from income General Fund.....	\$5,244.64	By cash paid on account of Repairs.....	\$ 163.63
" " " " Walker Fund.....	1,932.71	" " " " Fuel and Light.....	299.81
" " " " J. W. Randall Fund.....	260.00	" " " " Insurance.....	73.60
" " " " H. F. Walcott Fund.....	367.97	" " " " General Expense.....	1,125.63
" " " " Entomological Fund.....	27.48	" " " " Salaries.....	8,680.00
" " " " C. L. Flint Fund.....	257.38	" " " " Laboratory.....	20.32
" " " " Bulfinch St. Estate Fund.....	1,345.03	" " " " Museum.....	331.63
" " " " S. P. Pratt Fund.....	570.83	" " " " Library.....	748.94
" " " " Waterson Fund.....	396.37	" " " " Publications.....	1,243.83
" " " " Boston University.....	2,500.00	" " " " Walker Prizes.....	160.00
" " " " Massachusetts Inst. Technology.....	180.00	" " " " Trustees on account Insurance Sinking Fund.....	427.10
" " " " Admission Fees.....	1,430.00	Balance	4,079.34
" " " " Annual Assessments.....	144.43	Consisting of Donation.....	\$2,000.00
" " " " Museum Fees.....	211.54	Amounts in hand to pay for Publications and bookbinding ordered, and for cases and repairs necessary in Museum.....	2,079.34
" " " " Sale of Publications.....	150.00		
" " " " General Expense credit.....	2,000.00		
" " " " Donation.....	33.84		
" " " " Interest on deposit in Shawmut Bank.....	2.00		
" " " " Sale of Catalogue Cards of Library.....			
Total,	\$17,334.37	Total,	\$17,334.37
To cash received from Augustus Lowell, Trustee, for the Teachers' School of Science.....	\$3,000.00	By cash paid on account of Lectures and Supplies.....	\$1,821.54
To cash received from Interest on deposit in bank.....	8.00	Balance to new account.....	342.79
Balance from April 30, 1900.....	156.33		
Total,	\$3,164.33	Total,	\$2,164.33
To balance from April 30, 1900, Arms Fund.....	\$1,628.07	By cash paid for Supplies.....	\$ 3.12
" " " " Interest on deposit in bank.....	32.52	Balance to new account.....	1,655.47
Total,	\$1,658.59	Total,	\$1,658.59

It was voted to accept the reports of the Treasurer and of the Auditing Committee.

The report of the Trustees was accepted and placed on file.

It was voted to proceed to the election of officers for the ensuing year. The President appointed Prof. J. S. Kingsley and Dr. A. W. Grabau to act as tellers. After the ballots had been distributed and collected, it was announced that twenty-one ballots had been cast for each of the following candidates, who were then declared duly elected.

PRESIDENT,

CHARLES SEDGWICK MINOT.

VICE-PRESIDENTS,

CHARLES P. BOWDITCH.

HENRY W. HAYNES.

WILLIAM G. FARLOW.

CURATOR,

ALPHEUS HYATT.

SECRETARY,

GLOVER M. ALLEN.

TREASURER,

EDWARD T. BOUVÉ.

LIBRARIAN,

GLOVER M. ALLEN.

COUNCILLORS FOR THREE YEARS,

Miss CLARA E. CUMMINGS.

Miss SUSANNAH MINN^Y

JAMES H. EMERTON.

THOMAS A. WATSON

WILLIAM A. JEFFRIES.

SAMUEL WELLS.

GEORGE G. KENNEDY.

JOHN E. WOLFF.

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 CHICAGO, ILL. 60637

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LIST OF MEMBERS.

HONORARY MEMBERS.

Alexander Agassiz,	Cambridge.
Adolph Bastian,	Berlin.
Michael Foster.	Cambridge.
Ernst Haeckel,	Jena.
Joseph D. Hooker,	London.
Albert v. Kölliker,	Würzburg.
Henri Lacaze-Duthiers,	Paris.
Franz Leydig,	Würzburg.
Edward B. Tylor,	London.
Rudolph Virchow,	Berlin.

CORRESPONDING MEMBERS.

William Allen,	Boston.
James Anderson,	Liverpool, Eng.
Francis Archer,	Liverpool, Eng.
Francesco Ardissoni,	Milan, Italy.
Loring W. Bailey,	Frederickton, N. B.
A. S. Baldwin,	Jacksonville, Fla.
A. Constantine Barry,	Prairie du Sac, Wis.
Charles E. Beecher,	New Haven, Ct.
Hermann Behr,	San Francisco, Cal.
E. van Beneden,	Liège, Belgium.
William G. Binney,	Burlington, N. J.
Nathaniel H. Bishop,	Lake George, N. Y.
William P. Blake,	New Haven, Ct.
E. L. Bouvier,	Paris, France.
William H. Brewer,	New Haven, Ct.
William K. Brooks,	Baltimore, Md.
John Brown,	New York, N. Y.
Giovanni Capellini,	Bologna, Italy.
Antonio del Castillo,	Mexico, Mex.
Ferdinand Cohn,	Breslau, Germany.
Guido Cora,	Rome, Italy.
ohn M. Coulter,	Chicago, Ill.

368 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Hermann Credner,
Ezra T. Cresson,
Josiah Curtis,

Leipsic, Germany.
Philadelphia, Pa.
Washington, D. C.

Henry Davis,
William Boyd Dawkins,
William Dean,
Anton Dohrn,
Sanford B. Dole,
Henry E. Dresser,
Paul B. DuChaillu,
W. T. T. Dyer,

McGregor, Iowa.
Manchester, Eng.
Bangkok, Siam.
Naples, Italy.
Honolulu, H. I.
Kent, Eng.
New York, N. Y.
London, Eng.

Arthur M. Edwards,
William H. Edwards,
D. G. Elliot,
Sigmund Exner,

Newark, N. J.
Coalburg, W. Va.
Chicago, Ill.
Vienna, Austria.

Roswell Field,
F. Fouqué,

Gill.
Paris, France.

M. Ganin,
J. T. Gardner,
Albert Gaudry,
Archibald Geikie,
Theodore N. Gill,
Augustus R. Grote,
Albert C. L. G. Günther,
John T. Gulick,
L. H. Gulick,

Nice, France.
Washington, D. C.
Paris, France.
Edinburgh, Scotland.
Washington, D. C.
Hildesheim, Germany.
London, Eng.
Osaka, Japan.
Honolulu, Oahu.

Edwin Harrison,
James Hector,
Angelo Heilprin,
George Henshaw,
Henry Y. Hind,
Charles H. Hitchcock,
John Hjaltalin,
W. J. Holland,
Bernard A. Hoopes,
A. W. Howitt,
Oliver P. Hubbard,
Samuel Hubbard,

St. Louis, Mo.
Wellington, N. Z.
Philadelphia, Pa.
London, Eng.
Windsor, N. S.
Hanover, N. H.
Rejkyavik, Iceland.
Alleghany, Pa.
Philadelphia, Pa.
Melbourne, Vict.
Hanover, N. H.
San Francisco, Cal.

Christopher Johnson,
David S. Jordan,

Baltimore, Md.
Leland Stanford, Cal.

Clarence King,	Washington, D. C.
John King,	Boone, Iowa.
Cornelius Kollock,	Cheraw, S. C.
A. Kowalewsky,	St. Petersburg, Russia.
Carl Kupffer,	Munich, Germany.

Arnold Lang,	Zurich, Switzerland.
E. Ray Lankester,	London, Eng.
Joseph Leconte,	Berkeley, Cal.
R. von Lendenfeld,	Czernowitz, Austria.
J. Peter Lesley,	Milton.
A. M. Lévy,	Paris, France.
F. W. Lewis,	Philadelphia, Pa.
Richard Lydekker,	Harpندن, Eng.

Robert McLachlan,	London, Eng.
E. J. Marey,	Paris, France.
Paul Mayer,	Naples, Italy.
Joseph B. Meader,	Stoneham.
C. Hart Merriam,	Washington, D. C.
Charles L. Metz,	Madisonville, Ohio.
S. Wier Mitchell,	Philadelphia, Pa.
John Murray,	Edinburgh, Scotland.

Francis P. Nash,	Geneva, N. Y.
Alfred Newton,	Cambridge, Eng.

Henry F. Osborn,	New York, N. Y.
C. R. von Osten Sacken,	Heidelberg, Germany.
Emile Oustalet,	Paris, France.

Thomas F. Perley,	Portland, Me.
Félix Plateau,	Liège, Belgium.
Edward B. Poulton,	Oxford, Eng.
John W. Powell,	Washington, D. C.
Raphael Pumpelly,	Newport, R. I.

Richard Rathbun,	Washington, D. C.
Ferd von Richthofen,	Bonn, Germany.
Robert Ridgway,	Washington, D. C.
Heinrich Rosenbusch,	Heidelberg, Germany.

Henri de Saussure,	Geneva, Switzerland.
C. M. Scammon,	Washington, D. C.
Philip L. Sclater,	London, Eng.
A. R. C. Selwyn,	Ottawa, Can.
William Sharswood,	Philadelphia, Pa.
Hamilton L. Smith,	Geneva, N. Y.
Hermann Snellen,	Utrecht, Holland.

370 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Armand Thielens,
Tamerlan Thorell,
William Trelease,
Gustav Tschermak,

Tirlemont, Belgium.
Montpellier, France.
St. Louis, Mo.
Vienna, Austria.

Philip R. Uhler,

Baltimore, Md.

Addison E. Verrill,
Sydney H. Vines,

New Haven, Ct.
Oxford, Eng.

Henry A. Ward,
R. A. Ward,
Carl Wedt,
August Weismann,
George M. Wheeler,
William T. White,
R. P. Whitfield
Robert E. E. Wiedersheim,
Burt G. Wilder,
C. S. Wilkinson,
Edmund B. Wilson,
A. Smith Woodward,
Henry Woodward,
J. J. Woodward,

Rochester, N. Y.
Troy, N. Y.
Vienna, Austria.
Freiburg, Germany.
Washington, D. C.
New York, N. Y.
New York, N. Y.
Freiburg, Germany.
Ithaca, N. Y.
Sydney, N. S. W.
New York, N. Y.
London, Eng.
London, Eng.
Washington, D. C.

Ferdinand Zirkel,
Carl A. Zittel,

Leipsic, Germany.
Munich, Germany.

CORPORATE MEMBERS.

Samuel L. Abbot, M. D.,
John E. Alden,
Jane Alexander,
Glover M. Allen,
Henry F. Allen,
Joel A. Allen,
Edward P. Allis, Jr.,
Oakes Ames,
Arthur Amory,
Robert Amory, M. D.,
Clement W. Andrews,
S. Reed Anthony,
Nathan Appleton,
William S. Appleton,
R. T. Atkinson, M. D.,
Edward P. Austin,

90 Mt. Vernon St.
Newton.
91 Mt. Vernon St.
Cambridge.
Absent.
New York, N. Y.
Milwaukee, Wis.
North Easton.
133 Marlborough St.
279 Beacon St.
Chicago, Ill.
53 State St.
Somerset Club.
462 Beacon St.
Wakefield.
Absent.

Lucas Baker,	Absent.
Francis N. Balch,	23 Court St.
Edward E. Bancroft, M. D.,	Absent.
Edward A. Bangs,	240 Beacon St.
Outram Bangs,	240 Beacon St.
James M. Barnard,	Milton.
Walter B. Barrows,	Absent.
George H. Barton,	Mass. Inst. of Technology.
Charles F. Batchelder,	Cambridge.
George W. Beaman,	Cambridge.
Mrs. George W. Beaman,	Cambridge.
Elizabeth E. Bickford,	19 Upton St.
Henry B. Bigelow,	251 Commonwealth Ave.
Joseph S. Bigelow, Jr.,	251 Commonwealth Ave.
Robert P. Bigelow,	Mass. Inst. of Technology.
William S. Bigelow, M. D.,	60 Beacon St.
Clarence J. Blake, M. D.,	226 Marlborough.
Francis Blake,	Auburndale.
James H. Blake,	Cambridge.
Albert N. Blodgett, M. D.,	51 Massachusetts Ave.
Mrs. Alice L. Boardman,	Absent.
Elizabeth D. Boardman,	416 Marlborough St.
Edward T. Bouvé,	436 Marlborough St.
Charles P. Bowditch,	28 State St.
Frederic C. Bowditch,	28 State St.
Henry P. Bowditch, M. D.,	Harvard Medical School.
Mary A. Bowers,	Wellesley.
Mrs. Ella F. Boyd,	Hyde Park.
Arthur C. Boyden,	Bridgewater.
Edward M. Brewer,	Milton.
Francis W. Brewer,	Hingham.
Mrs. Thomas M. Brewer,	233 Beacon St.
Willard S. Brewer,	Hingham.
Edwin T. Brewster,	Andover.
William Brewster,	Cambridge.
Albert P. Brigham,	Absent.
Henry Brooks,	Lincoln.
J. H. Brooks,	610 Sears Building.
Shepherd Brooks,	92 Beacon St.
J. Frank Brown,	Somerville.
Samuel N. Brown,	119 Commonwealth Ave.
Edward I. Browne,	53 State St.
Elizabeth B. Bryant,	Allston.
John Bryant, M. D.,	Cohasset.
William S. Bryant, M. D.,	53 State Street.
Charles Bullard,	North Cambridge.
William N. Bullard, M. D.,	89 Marlborough St.
Hermion C. Bumpus,	New York, N. Y.
John A. Burnham,	57 Commonwealth Ave.

372 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Arthur T. Cabot, M. D.,	1 Marlborough St.
Louis Cabot,	Brookline.
William B. Cabot,	Chestnut Hill.
Mrs. Gary N. Calkins,	New York, N. Y.
Alvin Carl,	Jamaica Plain.
Charles T. Carruth,	34 India St.
Mrs. J. B. Case,	468 Beacon St.
Arthur P. Chadbourne, M. D.,	225 Marlborough St.
Walter G. Chase,	Brookline.
Francis S. Child,	Absent.
Henry L. Clapp,	Roxbury.
Mrs. Mabel D. Clapp,	9 Massachusetts Ave.
John S. Clark,	646 Washington St.
T. W. B. Clark,	326 Atlantic Ave.
Cora H. Clarke,	91 Mt. Vernon St.
Eliot C. Clarke,	53 State St.
Collier Cobb,	Chapel Hill, N. C.
Edward W. Codman,	53 Marlborough St.
Helen Collamore,	317 Commonwealth Ave.
Frank S. Collins,	Malden.
Grace E. Cooley,	Wellesley.
Algernon Coolidge, M. D.,	81 Marlborough St.
John T. Coolidge,	148 Beacon St.
T. Jefferson Coolidge, Jr.,	184 Beacon St.
Charles B. Cory,	160 Boylston St.
Charles U. Cotting,	249 Commonwealth Ave.
Sarah H. Croker,	319 Commonwealth Ave.
William O. Crosby,	Boston Soc. Nat. Hist.
Charles R. Cross,	Mass. Inst. of Technology.
Clara E. Cummings,	Wellesley.
Allen Curtis,	191 Beacon St.
Lawrence Curtis,	15 Congress St.
Ulric Dahlgren,	Princeton, N. J.
William H. Dall,	Absent.
Reginald A. Daly,	Cambridge.
Ada Dana,	Newton.
John Dane,	29 Marlborough St.
F. Graef Darlington,	Absent.
Charles B. Davenport,	Chicago, Ill.
Andrew McF. Davis,	Cambridge.
James C. Davis,	70 Kilby St.
Simon Davis,	277 Beacon St.
William M. Davis,	Cambridge.
Henry G. Denny,	68 Devonshire St.
Franklin Dexter, M. D.,	148 Marlborough St.
F. Gordon Dexter,	55 Beacon St.
Gordon Dexter,	55 Beacon St.

Joseph S. Diller,	Cambridge.
George Dimmock,	Springfield.
Richard E. Dodge,	Absent.
Charles C. Doe,	South Newbury, Vt.
Thomas Doliber,	Brookline.
George B. Dorr,	18 Commonwealth Ave.
Johnathan Dorr,	27 School St.
George A. Dorsey,	Chicago, Ill.
G. W. W. Dove,	Andover, Mass.
Sarah A. Downs,	Absent.
Thomas Dwight, M. D.,	235 Beacon St.
Harrison G. Dyar,	Washington, D. C.
Raymond B. Earle,	Absent.
Charles R. Eastman,	Cambridgeport.
Charles L. Edwards,	Hartford, Conn.
Charles W. Elliot,	Cambridge.
Mrs. J. W. Elliot,	124 Beacon St.
Mary L. Ellis,	Cambridge.
James H. Emerton,	1 Clarendon St.
William Endicott,	33 Summer St.
Harold C. Ernst, M. D.,	Harvard Medical School.
James F. Estes,	Absent.
Arthur W. Fairbanks, M. D.,	422 Massachusetts Ave.
William G. Farlow, M. D.,	Cambridge.
Mrs. Eva D. Farquhar,	Roxbury.
Charles E. Faxon,	Jamaica Plain.
Dudley B. Fay,	287 Beacon St.
Henry H. Fay,	416 Beacon St.
Joseph S. Fay,	169 Commonwealth Ave.
Sarah B. Fay,	88 Mt. Vernon St.
Charles S. Fellows,	Fairbanks, Fla.
L. Carteret Fenno,	562 Atlantic Ave.
Charles H. Fernald,	Amherst.
J. Walter Fewkes,	Absent.
William L. W. Field,	Milton.
Frank S. Fiske,	U. S. Court House.
George W. Fitz, M. D.,	483 Beacon St.
Augustus Flagg,	274 Clarendon St.
Charles F. Folsom, M. D.,	15 Marlborough St.
Justus W. Folsom,	Yellow Springs, Ohio.
Francis B. Forbes,	65 Marlborough St.
Eugene N. Foss,	Jamaica Plain.
Frank H. Foster,	Claremont, N. H.
John Foster,	113 Broad St.
William Foster,	Absent.
Harriet E. Freeman,	37 Union Park.

374 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

Mrs. James G. Freeman,
Nathaniel S. French,
Sophia W. French,
Ellen Frothingham,
Charles Fry,
Mrs. Sarah S. Fuller,

470 Beacon St.
West Roxbury.
Wollaston.
191 Commonwealth Ave.
40 Water St.
P. O. Box 1303.

Charles W. Galloupe,
T. W. Galloway,
William F. Ganong,
Edward G. Gardiner,
John L. Gardner,
George M. Garland, M. D.,
George W. Gay, M. D.,
B. W. Gilbert,
George L. Goodale, M. D.,
Harold B. Goodrich,
Mrs. Mary T. Gorham,
Amadeus W. Grabau,
John Y. Graham,
Francis C. Gray,
John C. Gray,
Mrs. C. W. Greenough,
Charles P. Greenough,
H. S. Greenough,
Henry S. Grew,
Leon S. Griswold,

45 Broad St.
Marshall, Mo.
Absent.
131 Mt. Vernon St.
51 Commonwealth Ave.
227 Newbury St.
665 Boylston St.
202 Purchase St.
Cambridge.
72 Westland Ave.
108 Marlborough St.
Boston Soc. Nat. Hist.
University, Ala.
7 Mt. Vernon Place.
176 Beacon St.
Jamaica Plain.
39 Court St.
Absent.
89 Beacon St.
Dorchester.

Minna B. Hall,
Susan M. Hallowell,
Mrs. M. L. Hammatt,
Ida S. Hammerle,
Charles Harrington, M. D.,
T. W. Harris,
Francis R. Hart,
George A. Hathaway,
Franklin Haven,
Gustavus Hay, M. D.,
Henry W. Haynes,
Roland Hayward,
Charles E. Hellier,
Augustus Hemenway,
Mrs. Augustus Hemenway,
Joseph P. B. Henshaw,
Samuel Henshaw,
Warren W. Herman,
C. J. Herrick,
Francis H. Herrick,

Brookline.
Wellesley.
Hyde Park.
Roxbury.
Harvard Medical School
Absent.
Milton.
Cambridge.
97 Mt. Vernon St.
383 Marlborough St.
239 Beacon St.
346 Marlborough St.
57 Equitable Building.
273 Clarendon St.
273 Clarendon St.
77 Newbury St.
Cambridge.
P. O. Box 1848.
Granville, Ohio.
Cleveland, Ohio.

Ella J. Hill,	Absent.
Harriet A. Hill,	Belmont.
Mary H. Hinckley,	Mattapan.
John Hobbs,	99 St. Botolph St.
Walter E. Hobbs,	Stonybrook.
John Hogg,	280 Commonwealth Ave.
John Homans, M. D.,	164 Beacon St.
Robert C. Hooper,	448 Beacon St.
Mrs. S. E. Hooper,	Cambridge.
Samuel A. Hopkins, M. D.,	235 Marlborough St.
Garry de N. Hough, M. D.,	New Bedford.
Theodore Hough,	Mass. Inst. of Technology.
Oliver H. Howe, M. D.,	Cohasset.
Charles W. Hubbard,	133 Essex St.
John G. Hubbard,	Brookline.
L. L. Hubbard,	Absent.
Henry S. Hunnewell,	9 Park St.
Alpheus Hyatt,	Cambridge.
Mrs. Clara C. Hyatt,	Westchester, N. Y.
Charles E. Inches, M. D.,	386 Beacon St.
Catherine I. Ireland,	Cambridge.
John G. Jack,	Jamaica Plain.
Marian C. Jackson,	88 Marlborough St.
Robert T. Jackson,	Cambridge.
William D. Jackson,	Bridgewater.
Thomas A. Jaggar, Jr.,	Cambridge.
B. Joy Jeffries, M. D.,	15 Chestnut St.
William A. Jeffries,	P. O. Box 2013.
G. F. Jelly, M. D.,	69 Newbury St.
Charles W. Jenks,	Bedford.
Charles F. Jenney,	Hyde Park.
Herbert S. Jennings,	Ann Arbor, Mich.
Isabel L. Johnson,	467 Massachusetts Ave.
Marian H. Judd,	186 Commonwealth Ave.
Mrs. M. M. Kehew,	317 Beacon St.
Charles S. Kendall,	91 Federal St.
Mrs. Caroline A. Kennard,	Brookline.
George G. Kennedy, M. D.,	Readville.
Harris Kennedy, M. D.,	Readville.
Nathaniel T. Kidder,	Milton.
John S. Kingsley,	Tufts College.
Fred D. Lambert,	Tufts College.
Alfred C. Lane,	Absent.

376 PROCEEDINGS : BOSTON SOCIETY NATURAL HISTORY.

Amory A. Lawrence,
William Lawrence,
George W. Lee,
David F. Lincoln, M. D.,
James L. Little,
William R. Livermore,
Andrew J. Lloyd,
William C. Loring,
Charles Lowell,
James Arnold Lowell,
Mrs. Louisa F. Lowery,
F. B. Lund, M. D.,
Arthur T. Lyman,
Charles P. Lyman, M. D.,

George H. Mackay,
John W. McKim,
W. Duncan McKim,
J. Playfair McMurrich,
W. D. McPherson,
B. Pickman Mann,
Warren H. Manning,
Edward L. Mark,
Mrs. W. H. K. Marrs,
Vernon F. Marsters,
F. W. G. May,
Alfred G. Mayer,
Charles J. Maynard,
James Means,
Selah Merrill,
Gerrit S. Miller, Jr.,
Susannah Minns,
Charles S. Minot,
Mrs. Charles S. Minot,
James J. Minot,
Laurence Minot,
Robert S. Minot,
George Mixter,
Henry L. Moody,
Alexander Moore,
Margaret W. Morley,
Albro D. Morrill,
Albert P. Morse,
Edward S. Morse,
Elisha W. Morse,
Robert W. Morville, Jr.,
John Murdoch,
Albert L. Murdock,

59 Commonwealth Ave.
122 Commonwealth Ave.
Brookline.
78 Pinckney St.
Brookline.
Absent.
308 Newbury St.
2 Gloucester St.
149 Beacon St.
Chestnut Hill.
Absent.
529 Beacon St.
P. O. Box 1717.
50 Village St.

218 Commonwealth Ave
Suffolk Co. Probate Court
Portsmouth, N. H.
Absent.
South Framingham.
Absent.
Brookline.
Cambridge.
Absent.
Bloomington, Ind.
127 State St.
Brooklyn, N. Y.
West Newton.
196 Beacon St.
Absent.
Washington, D. C.
14 Louisburg Sq.
Harvard Medical School.
Hyde Park.
Absent.
24 Marlborough St.
39 Court St.
219 Beacon St.
Absent.
8 School St.
10 Louisburg Sq.
Clinton, N. Y.
Wellesley.
Salem.
Jamaica Plain.
Jamaica Plain.
Roxbury.
337 Massachusetts Ave.

Nathaniel C. Nash,	Cambridge.
Herbert V. Neal,	Absent.
James G. Needham,	Lake Forest, Ill.
Frederick H. Newell,	Absent.
Mrs. Edith J. Nichols,	294 Marlborough St.
Sereno D. Nickerson,	Masonic Temple.
William H. Niles,	Cambridge.
Grenville H. Norcross,	9 Commonwealth Ave.
Edward E. Norton,	419 Washington St.
William E. Norton,	Absent.
John Orne, Jr.,	Cambridge.
Alpheus S. Packard, M. D.,	Providence, R. I.
Mrs. Henrietta Page,	P. O. Box 44 (Back Bay Office).
Charles J. Paine,	Sears Building.
George H. Parker,	North Cambridge.
Edith A. Parkhurst,	Somerville.
George L. Parmelee,	Absent.
William Patten,	Hanover, N. H.
Francis H. Peabody,	113 Devonshire St.
Mrs. F. H. Peabody,	Care Kidder, Peabody & Co.
James E. Peabody,	Absent.
Edward C. Perkins,	706 Sears Building.
John C. Phillips,	299 Berkeley St.
Henry Pickering,	1 Otis Place.
Dudley L. Pickman,	98 Beacon St.
Wallace L. Pierce,	350 Beacon St.
David Pingree,	Salem.
Julia B. Platt,	Absent.
Alfred E. Preble,	Wilmington, Mass.
Nathan B. Prescott,	Jamaica Plain.
William G. Preston,	186 Devonshire St.
Frances C. Prince,	17 Joy St.
Thomas E. Proctor,	Topsfield.
Charles P. Putnam, M. D.,	63 Marlborough St.
Frederick W. Putnam,	Cambridge.
James J. Putnam, M. D.,	106 Marlborough St.
Motte A. Read,	Absent.
Mrs. William H. Reed,	37 Commonwealth Ave.
John P. Reynolds, M. D.,	416 Marlborough St.
Stephen H. Rhodes,	541 Commonwealth Ave.
W. E. C. Rich,	West Roxbury
Mrs. Ellen H. Richards,	Jamaica Plain.
George H. Richards,	14 Chestnut St.
Harriet E. Richards,	Brookline.
Robert H. Richards,	Jamaica Plain.

378 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

William L. Richardson, M. D.,
 Everett W. Ricker,
 William Z. Ripley,
 Thomas P. Ritchie,
 Reginald C. Robbins,
 Benjamin L. Robinson,
 Alfred P. Rockwell,
 Mrs. William B. Rogers,
 Flora G. Roper,
 A. Lawrence Rotch,
 William H. Ruddick, M. D.,
 Mrs. T. E. Ruggles,
 John D. Runkle,
 Frederick W. Russell, M. D.,

William E. Safford,
 Lillian V. Sampson,
 Charles S. Sargent,
 Dudley A. Sargent, M. D.,
 Frederick Le R. Sargent,
 Mrs. Marian E. Y. Saville,
 Marshall H. Saville,
 Henry Sayles,
 Alfred L. T. Schaper, M. D.,
 Samuel H. Scudder,
 John H. Sears,
 Mrs. Mary L. Seavey,
 William T. Sedgwick,
 Nathaniel S. Shaler,
 J. C. Sharp, Jr.,
 Stephen P. Sharples,
 Mrs. J. M. Arms Sheldon,
 George H. Shull,
 A. D. Sinclair, M. D.,
 Charles C. Smith,
 Frederic F. Smith,
 J. D. Sornborger,
 Caroline G. Soule,
 A. W. Spencer,
 Charles J. Sprague,
 F. P. Sprague,
 Myles Standish, M. D.,
 Frank F. Stanley,
 George E. Stone,
 Charles S. Street,
 Mrs. Charles P. Strong,
 William C. Sturgis,
 John O. Sumner,

225 Commonwealth Ave.
 City Hall.
 Mass. Inst. of Technology.
 Newton Highlands.
 378 Washington St.
 Cambridge.
 281 Beacon St.
 117 Marlborough St.
 Revere.
 53 State St.
 502 E. Broadway.
 Milton.
 Mass. Inst. of Technology.
 Winchendon.

Absent.
 Germantown, Pa.
 Brookline.
 Cambridge.
 Absent.
 Waban.
 Absent.
 Somerset Club.
 Harvard Medical School.
 Cambridge.
 Salem.
 153 Strathmore Road.
 Mass. Inst. of Technology.
 Cambridge.
 54 Commonwealth Ave.
 13 Broad St.
 108 Mt. Vernon St.
 Yellow Springs, Ohio.
 35 Newbury St.
 286 Marlborough St.
 Ludlow.
 Cambridge.
 Brookline.
 31 State St.
 380 Marlborough St.
 229 Commonwealth Ave.
 67 St. James Ave.
 108 Summer St.
 Amherst.
 Absent.
 Cambridge.
 New Haven, Conn.
 Absent.

Charles W. Swan, M. D.,	Brookline.
J. Brooks Taft,	Absent.
Ralph S. Tarr,	Absent.
Levi L. Thaxter,	18 Tremont St.
Roland Thaxter,	Cambridge.
John E. Thayer,	Lancaster.
Augustus L. Thorndike,	722 Tremont Building.
Townsend W. Thorndike,	22 Newbury St.
G. Francis Topliff,	48 Congress St.
Mrs. Helen M. Tower,	Cambridgeport.
Samuel F. Tower,	English High School.
William L. Tower,	Yellow Springs, Ohio.
Frederick Tuckerman, M. D.,	Amherst.
William Tudor,	Absent.
William L. Underwood,	Belmont.
Warren Upham,	Absent.
J. F. Urie, M. D.,	Absent.
Balfour H. Van Vleck,	Boston Soc. of Nat. Hist.
T. Wayland Vaughan,	Absent.
Joseph Vila,	Absent.
M. Edward Wadsworth,	Absent.
Oliver F. Wadsworth, M. D.,	526 Beacon St.
Robert Wainwright,	Absent.
Frederick C. Waite,	Chicago, Ill.
Mary L. Ware,	41 Brimmer St.
C. H. Warren,	Mass. Inst. of Technology.
Joseph W. Warren, M. D.,	Absent.
M. Eva Warren,	Somerville.
Mrs. Elizabeth S. Watson,	Absent.
Thomas A. Watson,	Weymouth.
Clarence M. Weed,	Durham, N. H.
Andrew G. Weeks,	400 Beacon St.
Andrew G. Weeks, Jr.,	360 Washington St.
Charles G. Weld, M. D.,	6 Commonwealth Ave.
Samuel M. Weld,	North Chatham.
Samuel Wells,	45 Commonwealth Ave.
William P. Wesselhoeft, M. D.,	176 Commonwealth Ave.
Arthur W. Weyssse,	Mass. Inst. of Technology.
James C. White, M. D.,	250 Marlborough St.
Charles O. Whitman,	Chicago, Ill.
Henry M. Whitney,	Metropolitan S. S. Co.
Solon F. Whitney,	Watertown.
William F. Whitney, M. D.,	228 Marlborough St.
W. R. Whitney,	Mass. Inst. of Technology.
W. L. Whittemore,	Milford, N. H.

380 PROCEEDINGS: BOSTON SOCIETY NATURAL HISTORY.

George Wigglesworth,
Thomas Wigglesworth,
Mary A. Willcox,
Emile F. Williams,
Henry V. Wilson,
William P. Wilson,
Clifton E. Wing, M. D.,
Guy M. Winslow,
John E. Wolff,
Edward S. Wood, M. D.,
Elvira Wood.
J. Edmund Woodman,
Frederick A. Woods, M. D.,
Jay B. Woodworth,
William McM. Woodworth,
G. Frederick Wright,

E. Bentley Young,

Francoes Zirngiebel,

53 State St.
36 Hawley St.
Wellesley.
687 Boylston St.
Chapel Hill, N. C.
Absent.
Roxbury.
Auburndale.
Cambridge
Harvard Medical School.
Mass. Inst. of Technology.
Cambridge.
Brookline.
Cambridge.
Cambridge.
Oberlin, Ohio.

104 Appleton St.

Roxbury.

PATRONS.

Loring W. Bailey.
W. W. Bailey.
James M. Barnard.
Miss Emeline Binney.
Mrs. Mary G. P. Binney.

George R. Carter.
Henry Cross.

C. W. Galloupe.

Nathan Matthews.
John J. May.
Samuel May.

Henry Sayles.
Mrs. G. H. Shaw.
Charles J. Sprague.
W. W. Stone

Thomas Wigglesworth.

No. 18.— *The Polychaeta of the Puget Sound Region.*

BY HERBERT PARLIN JOHNSON.

THE following account of the Polychaeta of Puget Sound and neighboring waters is primarily based upon a collection made by Nathan R. Harrington, lately deceased, a member of the Columbia University Zoological Expedition to that region in the summer of 1896. The collection, comprising thirty-four species belonging to seventeen families, was sent to me in January, 1898. Preliminary examination showed that the collection, although meagre, in part poorly preserved, and almost destitute of data, contained much of interest. It seemed best, however, to defer any publication of results until more and better material could be obtained. Thanks to the good efforts of several collectors, notably Prof. William E. Ritter and Miss Alice Robertson, both of the University of California, very substantial additions have been made to the original collection. These, together with two species from Victoria, B. C., kindly contributed by Prof. William A. Herdman, raise the total number of species to fifty-one, distributed in thirty-four genera and twenty-six families (see Table, p. 384)—practically all the Polychaeta known to occur in the Puget Sound region.¹ They cannot reasonably be supposed to represent more than a fourth or even a fifth of the actual Polychaete fauna. Nearly all the collecting thus far has been between tide-marks. Dredging has been small in amount and limited to very moderate depths (not over thirty fathoms); and the entire absence of pelagic forms—with the possible exception of *Aricideopsis megalops*—would indicate but slight use of the tow-net.

¹ Ehlers ('68) describes eight species from the Pacific Coast; five of these (*Nereis agassizi*, *N. procera*, *N. verrillosa*, *N. virens* and *Nephtys coeca*) have been found in Puget Sound or vicinity.

Baird ('63) describes nine species, all from Esquimalt Harbor, Vancouver Island. Four of these, *Polynoe (Lepidonotus) insignis*, *lordi*, *fragilis*, and *Nereis foliata* (= *N. virens* Sars) have been identified, and an account is given of them. *Lepidonotus grubel* is in all probability the same as *Polynoe insignis*. There remain unidentified only four of Baird's species (*Harmothoe unicolor*, *Nereis bicanaliculata*, *Glycera corrugata*, and *Sabellaria saxicava*). These it is practically impossible to identify with certainty from Baird's descriptions.

Although comparison has been carefully made with the descriptions of Japanese Polychaeta given by Grube ('77) and by von Marenzeller ('79 and '84), no species, with the sole exception of the widely ranging *Harmothoe imbricata*, has been found to inhabit both sides of the Pacific. This is not surprising when we consider that nearly all of the sixty-two species of Grube's and Marenzeller's lists are from the southern portions of Japan, and therefore belong to the Indo-Pacific fauna, not to the circumboreal. But, on the other hand, comparison of Puget Sound Annelids with those of Bering Sea (Wirén, '83; Marenzeller, '90) also shows absolute dissimilarity. So far as known, the Polychaeta of the more northern parts of Bering Sea — the only ones of that region dealt with by Wirén and von Marenzeller — are practically those of the Arctic and North Atlantic (*i. e.*, are circumboreal) with very little admixture of forms peculiar to the North Pacific. In Wirén's list of twenty-nine species there is not one which can be regarded as belonging distinctively to the North Pacific. Von Marenzeller's list of twenty-four (exclusive of eight previously given by Wirén) affords only two new species; the others are well-known inhabitants of the shores of Scandinavia, Iceland, Greenland, or north-eastern America. The data as yet available are wholly insufficient to justify even a rough estimate of what proportion of the Puget Sound Annelids range far to the northward and eastward along the Aleutian chain. From such a category should of course be excluded purely circumboreal and North-Atlantic species (*e. g.*, *Polynoe* (*Lepidonotus*) *squamata*, *Harmothoe imbricata*, *Nereis virens*), as these are no more characteristic of the Pacific than of the Atlantic. When the extensive series of Polychaeta collected by Professor Ritter and Dr. Coe during the Harriman Alaskan Expedition of 1899 shall have been worked up it will doubtless be found to contain many species which range southward to Puget Sound and beyond.

Descriptions of localities where collecting was done by the Columbia Expedition have already been given in the general reports by members of the Expedition ('97, '97a); and the topography of the region, with indication of collecting stations, is shown in a map published with the first of these reports. In many instances the authors mention the occurrence of Annelids; but it is not always possible to determine accurately what species is meant. Moreover, several species are mentioned — by generic name at least — that are not represented in the collections.

In the summers of '97, '98, and '99 Miss Robertson collected in the vicinity of Seattle, a region much further up the Sound than that investigated by the Columbia University Expedition. About Seattle the shores are generally beaches of muddy sand, but sometimes clean sand, as is the case between Duwanish Head and Alki Point. Alki Point itself is rocky, and in 1898 numerous Annelids were found between and under the stones. Under the bluff on the north shore of Port Orchard Channel (stretching westward from the Sound) extends Pleasant Beach, composed of muddy sand. Numerous burrowing forms are from this locality. On this beach Professor Ritter collected several species of Polychaeta in 1899.

Following is a list of the species represented in the various collections, which shows, so far as known, the local and the geographical distribution of each species. For convenience' sake, the two districts explored by the Columbia University Expedition are designated "Port Townsend Region" (including Sequim Bay, Discovery Bay, Scow Bay, and Hood's Canal), and "Neah Bay" (at the entrance of Straits of Juan de Fuca); while that portion of Puget Sound investigated by Miss Robertson and Professor Ritter is indicated as "Seattle Region" and comprises not only the immediate vicinity of Seattle but also Port Orchard Channel and its shores—Orchard Point, Mud Bay, "Port Orchard," Pleasant Beach, and Channel Rocks. A + indicates occurrence of a species in any given region.

Two species (*Northia iridescens* sp. nov. and *Sternaspis fossor* (?) Stimpson) were dredged by Prof. W. A. Herdman at Victoria, Vancouver Island, B. C.

		Neah Bay.	Port Townsend Region.	Seattle Region.	Geographical Distribution.
	LEVINSENIIDAE.				
29.	<i>Aricideopsis megalops</i> gen. et sp. nov.		+		
	MAGELONIDAE.				
30.	<i>Magelona longicornis</i> sp. nov.		+		
	CAPITELLIDAE.				
31.	<i>Capitella dizonata</i> sp. nov.		+		
	CHLORAEIMIDAE.				
32.	<i>Trophonia papillata</i> sp. nov.		+		Southward; Shelter Cove, Cal.
33.	<i>Flabelligera infundibularis</i> sp. nov.	+			
	STERNASPIDAE.				
34.	<i>Sternaspis fossor</i> (?) Stimp.	+			Victoria, B. C. (Herdman); Bering Sea, Japan (Marenzeller); N. E. coast North America.
	MALDANIDAE.				
35.	<i>Clymenella rubrocincta</i> sp. nov.	+	+		Southward to San Pedro, Cal.
36.	<i>Nicomache personata</i> sp. nov.		+		
	AMMOCHARIDAE.				
37.	<i>Ammochares occidentalis</i> sp. nov.		+		
	ARENICOLIDAE.				
38.	<i>Arenicola claparedei</i> Lev.	+	+		Mediterranean.
	CIRRATULIDAE.				
39.	<i>Cirratulus cingulatus</i> sp. nov.		+	+	
40.	<i>C. robustus</i> sp. nov.	+	+	+	
	AMPHICTENIDAE.				
41.	<i>Pectinaria brevicoma</i> sp. nov.		+		
	AMPHARETIDAE.				
42.	<i>Sabellides anops</i> sp. nov.		+		
	TEREBELLIDAE.				
43.	<i>Amphitrite robusta</i> sp. nov.		+	+	
44.	<i>A. spiralis</i> sp. nov.			+	
45.	<i>Lanice heterobranchia</i> sp. nov.				
46.	<i>Thelepus crispus</i> sp. nov.		+		Southward to San Francisco.
	SABELLIDAE.				
47.	<i>Bispira polymorpha</i> sp. nov.	+	+	+	Southward to Monterey Bay.
48.	<i>Megachone aurantiaca</i> gen. et sp. nov.		+		
	ERIOGRAPHIDAE.				
49.	<i>Myxicola pacifica</i> sp. nov.			+	
	SERPULIDAE.				
50.	<i>Serpula columbiana</i> sp. nov.		+	+	Southward to San Francisco.
51.	<i>Serpula zygophora</i> sp. nov.			+	Northward (?).

The entire absence of Phyllodocidae and Opheliidae from a collection of this size and representative character is remarkable. The Eunicidae and Chaetopteridae are represented, the former by several headless fragments of some large species, and the latter by numerous long, annulated, empty tubes.

For any zoologist devoted to the study of living animals, the examination and description of a collection of preserved specimens, gathered by others in a region he has never visited, is likely to prove an irksome and unprofitable task. In the present instance, however, the task has been enlivened by the discovery of several very interesting forms. First and foremost should be mentioned *Trypanosyllis gemmipara*, a Syllidian with alternation of generations in which the sexual zooids, instead of forming a linear series, arise by collateral budding near the posterior extremity. *Harmothoe tuta*, with its great number of asymmetrical somites, also deserves notice; and as regards zoogeography, the discovery of a Pacific species of *Magelona*, the finding of a genuine *Hemipodia* in the Northern Hemisphere, and the confirmation of Gamble and Ashworth's (1900) statement regarding the occurrence of *Arenicola claparedei* on the west coast of America, are worthy of note.

I gladly avail myself of this opportunity to express my sincere and hearty thanks to Prof. C. O. Whitman, who generously placed at my disposal an investigator's room at the Marine Biological Laboratory during the latter part of the summer of 1900; to Prof. E. L. Mark, of Harvard, to whom I am indebted for laboratory privileges at the Museum of Comparative Zoology; and to Dr. Wm. M. Woodworth for permission to make use of the Polychaete collections of the same institution.

POLYNOIDAE.

1. *Polynoe squamata* (L.) Aud. and M.-Edwards.

Lepidonotus squamatus Leach. Zoological miscellany, London, 1816.

This well-known circumboreal species is represented by three specimens, probably from the vicinity of Port Townsend.

P. squamata occurs on the California coast as far south as Santa Monica, where a specimen was obtained for me by Mr. J. J. Rivers, the well-known entomologist. At Pacific Grove it is frequent in

dredgings at twelve fathoms and over, but I have never obtained it there between tide-marks. I have collected it just above low-water mark at Point Cavallo, on the northern shore of the Golden Gate, and even higher on the beach near Black Point, Sonoma County, about one hundred miles north of San Francisco. The specimens from Puget Sound are larger than any as yet collected from the California coast, but are inferior in size to New England specimens. It is probable that this species will be found to have a wide distribution along the eastern and western shores of the North Pacific, comparable to its dispersal on both sides of the North Atlantic.

2. ***Polynoe insignis*** (Baird).

Lepidonotus insignis Baird. Proc. zool. soc. London, Apr., 1863, p. 106.

Halosydna insignis Baird. Journ. Linn. soc. London, vol. 8. (Zoology), 1865, p. 188.

Polynoe brevisetosa (Kinberg) Johnson. Proc. Cal. acad. sciences, 3d ser., Zoology, vol. 1, 1897, p. 167. Figs. 24, 31, 40, 40a, 46, 46a.

This, the commonest Polynoid of the western coast of North America, is represented in the Puget Sound collections by several slender, darkly pigmented specimens commensal with *Thelepus crispus*, and a single specimen with remarkably thick and tuberculated elytra, obtained by the Columbia University Expedition; also by four specimens collected by Miss Robertson at Alki Point.

With the exception of *Harmothoe imbricata* this species has the widest known distribution along our western sea-board of any of its family, ranging from San Diego to Kadiak.¹ South of Point Concepcion it is rare, at least inshore, being almost wholly replaced by *P. californica*.² Its remarkable variations according to habitat have been described elsewhere (*vide* Johnson, '97, p. 167).

The identification of this species with the *Halosydna brevisetosa* of Kinberg ('55; '58, p. 18), as given by me in the "Preliminary Account" ('97), was undoubtedly characterized by too little confidence in the accuracy of Kinberg's figures and too much influenced by his statement that *Halosydna brevisetosa* was collected in San-salito Bay, near San Francisco. As *P. insignis* is the only Poly-

¹ A small collection of Polychaeta from Kadiak Island, including a single *P. insignis*, was gathered by Mr. Cloudsley Rutter, and kindly loaned to me for examination and description by Stanford University.

² Name changed from *P. reticulata* Johnson ('97) as the latter name is preoccupied.

noid with eighteen pairs of elytra I have ever seen from that portion of the coast, it is highly probable that Kinberg's species came from another part of the world. *P. insignis* was described by Baird in 1863 from specimens collected by J. K. Lord at Esquimalt, Vancouver Island. His *Lepidonotus grubei*, described at the same time (and subsequently) with the foregoing, is in all probability a mere color variety of *P. insignis*.

3. ***Polynoe lordi* (Baird).**

Lepidonotus lordi Baird. Proc. zool. soc. London, Apr., 1863.

Halosydna lordi Baird. Journ. Linn. soc. London, vol. 8 (Zoology), 1865, p. 190.

Polynoe lordi Johnson. Proc. Cal. acad. sciences, 3d ser., Zoology, vol. 1, 1897, p. 175. Figs. 35, 44, 51.

As in the case of *P. insignis* and *P. fragilis*, the Puget Sound region may be regarded as the type locality of the present species. All three were collected by J. K. Lord at Esquimalt, Vancouver Island. For an instructive and entertaining account of this curious Polynoid's habits and habitat, the reader is referred to Lord's "Naturalist in Vancouver Island and British Columbia," vol. 2, page 9 ('66). As this somewhat rare work is doubtless inaccessible to many, I quote somewhat at length from Lord's account. Speaking of *Fissurella cratitia*, the host of *P. lordi*, he says: "I had found him at last and at home, so pounced upon him as a lawful and legitimate prize. Knife and hammer soon severed his close attachment to the rocks; and turning him up, to take a peep at his powerful ring of muscle and strangely-formed breathing apparatus, I spied a worm evidently very uneasy, about three inches long, brown, and in shape like an ancient dagger blade. He appeared to me to be wriggling out from betwixt the folds of the foot or the mantle, and apparently most anxious to escape.... In displacing other shells, I found in nearly every one a similar tenant: the secret was discovered, the worm was a parasite, that lived in peace and good-fellowship with the Keyhole.... That the parasite worm does no harm is clearly proved by the healthy state of the mollusc in whose shell it takes up its abode.... On more carefully examining the position of the worm I found it was invariably coiled away in a semi-circle under the foot, like a ribbon on its edge, never flat. This seems to me a wise provision; for the pressure of the muscles when the limpet grips the rock would crush a soft-bodied worm to death, if flat; but by being edge on, which is the position

chosen, all risk of harm is avoided, as it fits in a cleft between two layers of soft material. . . . At least four out of every six contained a parasite, and, what is rather strange, the worms were nearly all of one size."

Later collectors have found it not uncommon in that region. The Columbia University collection contains four specimens, probably from Neah Bay, as the species is mentioned by Harrington and Griffin ('97) as having been found there "on *Fissurella*." Miss Robertson's collections afford only a single fragmentary specimen from Alki Point. I have several from Anacortes, collected by Miss Louise M. Carpenter, of Berkeley, Cal. These last occurred under the mantle of specimens of *Glyphis aspera*, preserved with the Annelids. This Gastropod is undoubtedly the usual host, but I have found it also in the gill-groove of *Cryptochiton stelleri*, and once on the Leather Star (*Dermasterias imbricata*), crawling on the aboral surface. The southern limit, so far as known, is Point San Pedro, about twelve miles south of San Francisco. Two specimens were found at that locality by Prof. W. J. Raymond of the University of California, who kindly placed them at my disposal. Although about eighteen specimens of *Glyphis aspera* were examined, only these two specimens of *P. lordi* were obtained. Like *Polynoe fragilis*, this species becomes more abundant northward. Every specimen of *Glyphis aspera* brought from Anacortes by Miss Carpenter had one or two examples of *P. lordi* under its mantle; and Lord states the proportion to be "at least four out of every six."

Two of the Columbia University specimens have almost no pigment. Even the brown zone on the ninth somite, so constant a feature of this species, cannot be made out in one specimen. This example is remarkable also for its size, having 83 somites and 41 pairs of elytra.

P. lordi, like *Lepidametria commensalis* (Webster, '79), *Polynoe gigas* Johnson, and *Harmothoe tuta* (Grube) often has asymmetrical somites in the posterior portion of the body. In one of the specimens from Anacortes the thirty-first somite is asymmetrical (cirriferous on the right side, elytriferous on the left). In a specimen from Dillon's Beach, Sonoma Co., Cal., there are as many as nine asymmetrical somites, and yet there are the same number of elytra (27) on both sides. The elytra on the right side are borne on somites 2, 4, 5, 7 . . . 23, 26, 28, 29, 31, 33, 35, 37, **38, 40, 42**,

44, 46, 48, 50, 52; and on the left side on somites 2, 4, 5 . . . 23, 26, 28, 29, 31, 33, 35, 37, 39, 41, 43, 44, 45, 47, 48, 50. The asymmetrical somites are printed in heavier type.

4. **Polynoe pulchra** Johnson.

Polynoe pulchra Johnson. Proc. Cal. acad. sciences, 3d ser., Zoology, vol. 1, 1897, p. 177. Figs. 34, 43, 43a, 50, 50a, 50b.

The species of scaly annelid referred to by Harrington and Griffin ('97) as occurring on *Holothuria californica* is without much doubt *P. pulchra*, as I have found it a frequent commensal or parasite of that Holothurian. It is well represented in the Columbia collection. None of the specimens exhibits dark brown or black markings on the elytra, but all appear to have had the protective reddish or flesh tints characteristic of the individuals found on *Holothuria californica*.

5. **Polynoe fragilis** (Baird). Pl. 1, fig. 1.

Lepidonotus fragilis Baird. Proc. zool. soc. London, Apr., 1863.

Halosydna fragilis Baird. Journ. Linn. soc. London, vol. 8 (Zoology), 1865, p. 190.

Polynoe fragilis Johnson. Proc. Cal. acad. sciences, 3d ser., Zoology, vol. 1, 1897, p. 179. Figs. 36, 45, 52, 52a, 52b.

Numerous specimens from all three districts of the Puget Sound region. As stated in the "Preliminary Account" (Johnson, '97, p. 180) this species is much more plentiful in the Puget Sound region than on the California coast, where I have collected it only in San Francisco Bay, and only three or four specimens in as many years. Its great abundance at Port Orchard is noted by Miss Robertson as follows: "Twenty specimens were taken from twenty-seven or twenty-eight Star-fishes. Several times two and in one instance three, were found on a single Star-fish."

The frequent absence of ventral cirri is a striking peculiarity. Even when present, the ventral cirrus is very diminutive; but, on the other hand, its absence on all the parapodia seems to be a rare occurrence. Of the twenty-nine examples at my command, only one (and an imperfect specimen at that) is entirely destitute of ventral cirri. In not a single individual, however, is every parapodium provided with a ventral cirrus.

6. **Harmothoe imbricata** (L.) Malmgren.

This ubiquitous species was collected by the Columbia Expedition, also by Miss Robertson at Alki Point and at other places. Most of the specimens are of the usual greenish gray tint with

mottled, iron-gray elytra. One of the largest specimens obtained at Alki Point has numerous undeveloped ova attached to the dorsal setae and in the intersegmental furrows. These bunches of ova are only partially covered by the elytra.

7. **Harmothoe iphionelloides** sp. nov. Pl. 1, figs. 2-7.

Form short, broad, and flattened; width, including elytra, two fifths of length; dorsum and prostomium completely covered by elytra, which overlap extensively; somites, 36; elytra, 15 pairs, borne on somites 2, 4, 5, 7 . . . 23, 26, 29, 32.

Prostomium (Fig. 2) broad, transverse diameter exceeding the longitudinal; distinctly bilobed with median sulcus; the lobes ovoid, rounded in front. Palpi stout, fusiform, minutely papillated, transversely ringed with grooves, acuminate. Tentacle with immense basal joint, nearly one half its length; terminal segment slightly papillate, subulate, unpigmented. Antennae with basal joints about as long as tentacle, slightly bulbous near tip, with subterminal dark band; slightly papillated. Eyes large, black, the posterior pair smaller and nearer together than the anterior pair.

Peristomial cirri (Fig. 2) much stouter than antennae, and about twice as long; with filiform papillae near tips; basal joints very long; subterminal bulbous enlargement, with dark pigment-zone.

Elytra thick, with large, rough, irregularly polygonal, flattened tubercles (Fig. 3), forming a pattern like alligator skin; tubercles increase in size from the concave (protected) side of elytron towards the convex and exposed portion; elytra become larger towards middle of series, and diminish again towards posterior end; ciliate on outer margin; except first pair, all elytra more or less strongly reniform, the concave edge of each embracing the preceding elytophore.

Parapodia (Fig. 4) rather long, thick, biramous; each ramus ending in a finger-like prolongation, into which the acicula extends. Dorsal cirrus extends beyond the setae; basal joint nearly one fifth its length with pin-head-like papillae towards the incrassated tip. Ventral cirrus subulate, slightly papillate. Ventral setae straw-colored, hardly extending beyond the longest dorsal (Fig. 4, *below* the dorsal cirrus), and only slightly stouter than the uppermost dorsal (*cf.* Figs. 5 and 6); slightly hooked at tip, with 12-20 "frills" of usual form. Dorsal setae white, forming a graduated series from uppermost stout, short, strongly-curved ones (Figs. 4 and 6) to the lower elongated slender ones (Figs. 7 *a, b*). The fine serrations extend nearly one half the length of seta, whether it be long or short.

Nephridial papillae very short, cylindrical, length and diameter about equal; begin at 8th and extend to 30th somite.

Length (approximately) 23 mm.; width, including setae, 10.5 mm.; dorso-ventral thickness, 3.5 mm.; proboscis, 4 mm.

A single specimen from Pleasant Beach, near Seattle, collected by Professor Ritter. It is chiefly notable for its great, overlapping elytra, with tuberculation resembling the areolae of *Harmothoe hirsuta*, or of *Iphionella*.

8. ***Harmothoe complanata*** sp. nov. Pl. 2, figs. 8-13.

Form of moderate length, flattened dorso-ventrally; breadth, including setae, two sevenths of length; number of somites, 36-38; elytra, 15 pairs, borne on somites 2, 4, 5, 7 . . . 23, 26, 29, 32.

Prostomium (Fig. 8) approximately six-sided, width and length equal, deeply incised for reception of basal joint of tentacle, indistinctly bilobed. Eyes four, minute, posterior pair dorsal, anterior pair dorso-lateral, and further apart than the posterior. Tentacle with short basal joint, which extends a little beyond the "peaks" of the prostomium, terminal portion nearly twice the length of the prostomium. Antennae very short, inserted below level of tentacle, two-jointed, less than one half the length of the prostomium. Palpi very thick at base, terete, gradually and uniformly tapering to an acute tip, barely papillate, as long as peristomial cirri.

Peristomial cirri long and slender, gradually and uniformly tapered, without subterminal dark band, slightly papillate.

Elytra (Fig. 10) thin, oval, translucent, with minute, scattered conical tubercles.

Parapodia (Fig. 9) long, rami distinct, finger-like tips long and slender. Dorsal cirrus like peristomial, long and slender, extending far beyond tips of setae, papillate. Ventral cirrus long, evenly tapered, papillate. Dorsal setae of two sorts: (a) a supra-acicular fascicle of very stout, minutely serrated setae (Fig. 11) which are the thickest in the foot; they are arranged in a whorl, the shortest being the uppermost and most anterior; (b) a smaller tuft of very slender, elongated, serrulate setae (Fig. 12) inserted in the finger-like process; these are considerably longer than the preceding, and much fewer (4-5 in number). The ventral setae (Fig. 9) are arranged in a graduated series of which the uppermost closely resembles in length, slenderness, and serrulation the dorsal setae of fascicle b; the middle and lower ones are of the more usual type (Fig. 13), with a series of "frills" near tip, beginning with very

minute ones and gradually increasing in size towards proximal end of seta.

Nephridial papillae begin at the 6th somite and extend to 36th; with acuminate tips.

Length of largest specimen, 21 mm.; width, including setae, 6 mm.

This species is represented by two imperfect specimens, one from Puget Sound, collected by Harrington, the other from Coronado, Cal., collected by me in July, 1895. Its living color is stated in my notes to be "orange-yellow," but the alcoholic specimen is pale brown. Elytra and dorsal cirri are easily detached. The occurrence of the species at localities so widely separated, and, so far as known, at no intermediate point, is certainly remarkable.

9. *Harmothoe pacifica* sp. nov. Pl. 2, figs. 14-17.

Form rather flattened, diminishing towards both head and posterior end; breadth, including setae, about four ninths of length. Somites, 37; elytra (wanting in specimen), 15 pairs, borne on somites 2, 4, 5 . . . 23, 26, 29, 32.

Prostomium very strongly bilobed, nearly twice as broad as long; "peaks" short and blunt, divaricate; lobes of prostomium separated by a wide, shallow groove. Basal joint of tentacle very thick, about the length of the prostomium. Antennae slender, considerably longer than prostomium, inserted below the level of tentacle; ciliate, their basal joints projecting beyond the peaks of the prostomium. Anterior pair of eyes laterally directed; just in front of the bulge of the prostomium; posterior pair dorsal, near base of prostomium, slightly nearer together than the anterior.

Peristomial cirri villous, without bulbous enlargement near tip.

Dorsal cirri (Fig. 14) very similar. Dorsal ramus short and stubby without finger-like process, bearing setae of two different forms (Figs. 15, 16) which grade into each other. The short curved ones are the more dorsal. All the dorsal setae are much more slender than the ventral. Ventral setae (Fig. 17) stout, hastate, with straight or slightly curved tips, and from two to twelve serrations. Ventral cirrus fusiform, papillate.

Length, 26.5 mm.; width across middle, including setae, 11.5 mm.

This species is represented by a single specimen, unfortunately without elytra and imperfect in other respects. It was collected by the Columbia Expedition. The species is probably scarce, as all efforts to obtain more specimens have thus far failed.

10. **Harmothoe tuta** (Grube). Pl. 2, figs. 18, 19. Pl. 3, figs. 20-22.

Polynoe tuta Grube. Arch. f. naturgesch., jahrg. 21, bd. 1, 1855, p. 82.

Halosydna tuta Baird. Journ. Linn. soc. London, vol. 8 (Zoology), 1865, p. 188.

Form elongated, of nearly uniform width throughout anterior two thirds, gradually tapering in posterior third to extremity; somites numerous and variable in number (77-83); elytra not all paired, 35-38 on each side; borne on somites 2, 4, 5, 7 . . . 23, 26, 29, 32 . . . ; general color of formalin specimens, very pale brown; a transverse band of darker brown on every somite of anterior half, and a median dark stripe.

Prostomium (Fig. 18) distinctly bilobed, median furrow extending to its base; lobes rounded anteriorly, widely sundered by the thick napiform basal joint of tentacle; eyes placed well forward, medium-sized, black; the anterior pair laterally, the posterior pair upwardly, directed. Basal joints of antennae inserted below the basal joint of tentacle, on underside of prostomium; distal segments of antennae and tentacle very short, nearly equal, not exceeding length of prostomium. Palpi also short, rapidly tapered to subulate tips; constricted at intervals in contraction; all cephalic appendages, like tentacular and dorsal cirri, sparsely beset with minute papillae.

Tentacular cirri considerably longer and more slender than tentacle; subterminal enlargement very slight.

Elytra slightly variable in shape, nearly orbicular (Fig. 20), some broadly reniform, strongly imbricated, meeting across median line; with very few microscopic tubercles, thin and translucent, suffused with smoky brown.

Parapodia (Figs. 18, 19) elongate, nearly or quite equal to width of dorsum between elytophores; dorsal setae rather numerous, much shorter and more slender than the ventral (Fig. 19), divaricate, slightly curved, rather coarsely serrated along convex border near tip (Fig. 21). Ventral setae numerous (over twenty), with about twelve "frills" near the slightly expanded tip. Point nearly straight, acute. Dorsal ramus short for this genus, with decided finger-like process, to tip of which the acicula extends. Ventral ramus stout, fleshy, with thick, stumpy, finger-like process which does not receive tip of acicula. Ventral cirrus short, abruptly tapering to a fine point.

Nephridial papillae extraordinarily long in large specimen, fully equal to ventral cirri; begin on the sixth somite and extend to the eighty-first in the larger, and to the seventy-fourth in the smaller specimen.

Length of larger specimen, 82 mm.; width, including parapodia and setae, 12 mm.; without setae, 10 mm.; without parapodia, 5 mm. *Length* of smaller specimen, 61 mm.; width, including parapodia and setae, 8 mm.; without setae, 6 mm.; without parapodia, 2 mm.

This interesting Polynoid is represented by two specimens in the collections, one obtained by Harrington and stated by him to be commensal in the tube of the largest species of "*Amphitrite*" found by the Expedition, — undoubtedly *Thelepus crispus* (see p. 428); the other collected by Miss Robertson at Alki Point. The latter is smaller and evidently younger than the former. The dimensions given in the diagnostic description show clearly the difference in the proportions of young and old.

The nearly colorless condition, as well as the great length of the body and the thin, translucent, smooth elytra, indicates plainly its constantly commensal habit. Forms like *P. insignis*, *P. californica*,¹ and *Harmothoe imbricata*, which are sometimes free-living, sometimes commensal, retain the pigment, often in heightened intensity, when they have either temporarily or permanently adopted the latter mode of life.

In spite of the excessive number of somites and elytra, the true relationship of this form is with the species grouped under the genus *Harmothoe* (*sensu extensiori*), and not with *Polynoe*, where numerous somites are much more frequent. The relationship with *Harmothoe* is shown (1) by the structure of the prostomium, (2) by the finger-like processes of the rami of the parapodia, and (3) by the sequence of the elytra from the 23d to the 32d somite (23, 26, 29, 32). A fourth character of less importance is the sparse papillation of the cirri — a feature almost invariably present in *Harmothoe*, and absent in *Polynoe*. The excessive number of somites and pairs of elytra possessed by not a few commensalistic or parasitic Polynoids is no doubt correlated with their mode of life; hence the unusual length attained by the commensal *Harmothoe tuta* need not surprise us, although such a length, and elytra in excess of 15 pairs, seem to be as rare in this genus as they are common in *Polynoe*.

¹ Synonym for *P. reticulata* Johnson which name is preoccupied by *P. reticulata* Claparède.

It is not unlikely that such highly modified forms as *Polynoe lordi*, *P. pulchra*, and *P. fragilis* have descended from *Harmothoe* stock and do not rightly belong in the genus *Polynoe*. The characters are a *mélange* of those of *Harmothoe* and *Polynoe* (*sensu ext.*). This may be taken to indicate that these commensals retain characters of the Polynoid ancestor from which typical *Polynoe* and *Harmothoe* have both descended. The structure of the prostomium, especially the presence of basal joints to the antennae, recalls *Harmothoe*; while the structure of the foot is more like that of *Polynoe*. The sequence of the elytra differs from that of both genera. These species certainly do not belong in the genus *Lepidasthenia*, where Darboux ('99) has placed them.

The asymmetrical somites (dorsal cirrus on one side, elytra on the other) constitute the most striking peculiarity of this species, and one which, so far as present knowledge goes, it shares only with *Polynoe gigas* Johnson ('97, p. 174), *Lepidametria commensalis* Webster ('79, p. 210), and *Polynoe lordi* (Baird). In *Polynoe gigas*, I have found at most two unsymmetrical somites; in *P. lordi*, from one to nine; for *Lepidametria* the number is not stated. In two specimens of *Harmothoe tuta* I have found, respectively, 15 and 16 asymmetrical somites! As in *P. gigas*, they are confined to the posterior part of the body (back of the 32d somite) whence the sequence of the elytra differs in different individuals. In the older specimen (Columbia University collection) there are 38 elytra on the right side and 35 on the left. In the younger specimen (No. 963) there are 38 elytra on the right side, 36 on the left. The asymmetrical somites of the former are: 38, 41, 43, 56, 57, 60, 61, 65, 69, 71, 77, 80, 81, 82, 83 — a total of 15; those of No. 963 are: 33, 37, 38, 39, 40, 41, 43, 45, 60, 62, 64, 66, 68, 70, 72, 74 — 16 in all.

The identification of the specimens from Puget Sound with the *Polynoe tuta* of Grube ('55), described from specimens collected at Sitka, seems reasonably safe, although his description takes no account of the diagnostically important structures of the head. The sequence of the elytra up to the thirty-second somite is precisely as stated by Grube. Beyond that point it differs in every different individual — a fact not perceived by Grube.

In no Polynoid has a normal asymmetrical somite been found in front of the 32d.

SIGALIONIDAE.

11. **Sthenelais fusca** Johnson.

Sthenelais fusca Johnson. Proc. Cal. acad. sciences, 3d ser., Zoology, vol. 1, 1897, p. 185. Figs. 60, 61, 64.

A single imperfect specimen of huge dimensions, including prostomium and 74 somites, was collected by Miss Robertson at Pleasant Beach in July, 1898. It is far larger than any specimen yet taken on the California coast. It measures 107 mm. in length (the entire worm must have been over twice as long) and 12 mm. in transverse diameter. The exposed surface of the elytra is rusty, with the exception of the first six pairs and scattered ones along the body, which are unpigmented and translucent.

HESIONIDAE.

12. **Podarke pugettensis** sp. nov. Pl. 3, figs. 23-25.

Body gradually tapering towards both ends; somites 50-54, the anterior three or four (Fig. 23) much shortened; the rest about four times broader than long.

Prostomium twice as broad as long, three-lobed in front, the lobes bearing the tentacle and dorsal pair of antennae (Fig. 23). No palpi; antennae 4, the ventral pair considerably stouter than the dorsal, and provided with a thick basal segment. Tentacle small, subulate, less than length of head. Eyes 4, contiguous, anterior pair slightly larger and farther apart than the posterior; both pairs with lens; retinal pigment brown.

Tentacular cirri on first three segments, two pairs to each, with distinct basal joints; dorsal cirri of 2d and 3d somites equal and longest.

Parapodia elongated (Fig. 24), exceeding half the width of dorsum; dorsal ramus and basal joint of dorsal cirrus fused; ventral ramus much longer, terminating in a conical, achaetous tip; 2 aciculae in each ramus. Dorsal cirrus notably longer than the parapod and setae; gradually tapered; ventral cirrus extending obliquely backward, somewhat beyond acute tip of ventral ramus.

Setae of two sorts, simple and compound, the former confined to the dorsal ramus; very few (Fig. 24) ventral setae, some with elongated appendages (Fig. 25) and some with short appendages — otherwise alike in form. They are arranged in a supra- and an infra-

acicular fascicle, from 13 to 20 setae in each. Anal cirri wanting in all the specimens.

Length of largest specimen, 25 mm.; width, 3.8 mm.

A few specimens from Alki Point, collected by Miss Robertson, Aug. 3, 1898. None are perfect, the tentacular and dorsal cirri, in particular, being very caducous. The species occurs also at Pacific Grove.

NEREIDAE.

13. ***Nereis virens*** M. Sars. Pl. 3, figs. 26–30.

Nereis virens Grube. Middendorff's Reise in den äussersten norden und osten Sibiriens, bd. 2, Zool., th. 1, 1851, p. 6. Taf. 1, figs. 2–6.

Alitta brandti Malmgren. Öfversigt af k. vet. akad. förhandlingar, Stockholm, 1865, p. 183.

N. foliata Baird. Appendix to John Keast Lord's "Naturalist in Vancouver Island and British Columbia," vol. 2, 1866, p. 347.

N. brandti Ehlers. Die borstenwürmer, 1868, p. 563.

I cannot agree with Ehlers ('68) and Malmgren ('65) that this North Pacific Nereid is distinct from *N. virens* of the coasts of Northeast America and of Northern Europe. I have compared specimens from the two oceans, and fail to find any differences that can be considered of specific value. It is apparently an interesting instance of discontinuous distribution, since the species seems not to attain high northern latitudes. The coast of Norway, the Gulf of St. Lawrence, and the Sea of Ochotsk (Grube) are the northern limits of its known distribution. It is likely to be found, however, on the more southern shores of Alaska. I have not found it on the California coast further south than Bolinas, about ten miles north of San Francisco.

The species attains a much greater size in the Pacific than in the Atlantic. Whereas an Atlantic *N. virens* of a length of 26 cm. in the contracted condition would be considered large, a length of 50 cm. and a diameter of 25 mm. under the same conditions are not infrequent dimensions on the western shores of North America (Fig. 26).

The *Heteronereis* of this species I have not seen, but as usual among Nereids, individuals attain sexual maturity in the ordinary or "atokous" form.

14. **Nereis vexillosa** Grube. Pls. 3 and 4, figs. 31-38.

Nereis vexillosa Grube. Middendorff's Reise, etc., bd. 2, Zool., th. 1, 1851, p. 4. Taf. 2, figs. 1, 5, 6.

N. arctica Grube. Ibid., p. 11. Taf. 1, fig. 7.

Heteronereis middendorffii Malmgren. Öfversigt af k. vet. akad. förhandlingar, Stockholm, 1865, p. 109.

This species, described and figured a half century ago by Grube, and subsequently by Ehlers ('68, p. 573), is one of the commonest Annelids all along the coast, from the Pribylof Islands to Santa Barbara. It apparently abounds in Puget Sound, judging from the fact that it occurs in all the collections from that region, and numerous in that of the Columbia Expedition. It is known to fishermen as the "pile-worm," on account of its habitat amongst the mussels and barnacles which cluster thickly upon the piles of wharves and bridges, and is in much requisition for bait. Upon the piles it seldom attains a length greater than 20 cm. and a diameter of 12 mm.; but in gravelly beaches, where it lives in company with *N. virens*, it grows to a somewhat larger size. Olive-green is its usual color in life, but this changes to a bright emerald-green or bluish green in alcohol. Tints of brown are very frequent in the more posterior parts, and sometimes the entire worm is brown or dusky.

The great dorsal lobe of the feet of the posterior portion of the body, carrying at its distal end the dorsal cirrus, increases notably in length with age, as may be seen by comparing Figs. 34 and 35, Pl. 4. The former represents a foot of a young female; the latter, the foot of a large, sexually-mature female. This great increase in length is probably not correlated with the advent of sexual maturity, as some individuals of very diminutive size have the dorsal lobes of considerable length. In passing caudad the dorsal lobes lengthen so gradually it is impossible to find a demarcation-point between long and short lobes. In the anterior region in front of the 12th foot the feet are of the form shown in Fig. 31, Pl. 3 (tenth foot).

The *Heteronereis* (epitokous form of Ehlers) is not uncommon (Figs. 32, 33). This condition is by no means confined to full-grown worms, but occurs in individuals having a length of 56 mm. and upward. The species also arrives at sexual maturity without becoming heteronereized, as I have noted in many instances.

15. **Nereis agassizi** Ehlers. Pl. 4, figs. 39-45.

Nereis agassizi Ehlers. Die borstenwürmer, 1868, p. 542. Pl. 23, fig. 1.

This beautiful Nereid is a tube-dweller. The secretion is furnished by the large glands opening on the dorsal aspect of the upper lobes of the feet (Figs. 44, 45*g*, Pl. 4), and is poured out so rapidly and copiously that a new tube is formed in a very few minutes when a worm is removed from its tube and placed in a jar of clean sea-water. The tube is rather tough and leathery, but very flexible and translucent, especially when newly secreted. The worms are gregarious, and great tangled ropy bunches of "eel-grass" (*Phyllospadix*) are often found, held together by the powerfully-adhesive secretion of a colony of *N. agassizi*. The species attains sexual maturity at the latitude of San Francisco in February and March. I have rarely seen the *Heteronereis* of this species.

N. agassizi does not attain a large size. The largest I have collected measures 63 mm. in length and 5 mm. in diameter, including parapodia and setae. Several small specimens have been brought from Puget Sound, and I have collected it at various points along the California coast as far south as Santa Barbara.

16. ***Nereis cyclurus*** Harrington. Pl. 4, fig. 46. Pl. 5, figs. 48-52.

Nereis cyclurus Harrington. Trans. N. Y. acad. sciences, vol. 16, 1897, p. 214. Pls. 16-18.

This remarkable species has been ably described by Harrington ('97), and its extraordinary commensalistic relations with the Hermit crab (*Eupagurus armatus* Dana) are discussed. The scanty material at command does not enable me to add anything of value. One of the striking features of this Nereid is the immense size and cup-like form of the peristomium (Figs. 46-48). This is undoubtedly for the protection of the prostomium, which when retracted is partially concealed within the concavity of the peristomium.

17. ***Nereis procera*** Ehlers. Pl. 4, fig. 47. Pl. 5, figs. 53-59.

Nereis procera Ehlers. Die borstenwürmer, 1868, p. 557. Pl. 23, fig. 2.

A very slender Nereid obtained by the Columbia Expedition undoubtedly belongs to this species. There are several specimens, none of which is complete. The species does not occur in the other collections from the Sound. There are no data as to depth or locality.

It is highly probable that this is the species of *Nereis* mentioned by Harrington and Griffin ('97a, p. 156) as dwelling in the tubes of a Chaetopterid. The extremely attenuated form of the body and

great number of somites suggest such a habitat; and the stout dorsal seta shown in Pl. 5, Fig. 59, is such as would properly belong to a tube-dwelling Nereid. These setae remind one of the "hooded crotchets" of *Nereis agassizi* (Pl. 4, Fig. 43), which is also a tube-dweller, but they are in fact compound setae with a much reduced appendage deeply sunk within the tip of the shaft. These setae are not found in the most anterior parapodia, but begin about the 40th foot. A seta of this form would be especially useful in clambering within the tube. These stout setae are only one or two in number in each foot (Figs. 54, 55, 56), and occur only in the dorsal ramus. There are no setae of the ordinary form in the dorsal ramus where these setae are present, except in two or three parapodia where the change is taking place (Fig. 54).

Ehlers's description of this species is based upon a single specimen collected by Alexander Agassiz in the Gulf of Georgia in 1859. This type, now deposited in the Museum of Comparative Zoology, I have had an opportunity to examine, and I find it of the same species as the specimens above mentioned.

None of the specimens is complete. Ehlers's example had a length of 125 mm. and 179 somites; a nearly perfect specimen in the Columbian collection measures 146 mm. and has 260 somites. It is evidently not full grown, for its greatest transverse diameter, including parapodia, does not exceed 3 mm., whereas Ehlers's specimen, which is the largest I have seen, has a diameter of 4 mm.

NEPHTHYDIDAE.

18. *Nephtys coeca* (Fabricius) Örsted.

Numerous examples from various localities — Neah Bay, Salmon Bay, and Pleasant Beach. The largest specimens measure 20 cm. and over in length, and 15 mm. across the thickest portion, including the parapodia. The species occurs northward along the Alaskan shores, in Bering Sea (Marenzeller, '90) and along the northern coast of Siberia (Wirén, '83). It extends southward along the California coast as far at least as San Francisco Bay, but the California specimens are pygmies as compared with those from Puget Sound and Alaska.

The species was long ago collected by Alex. Agassiz in the Gulf of Georgia and identified by Ehlers ("Die borstenwürmer," p. 588) as identical with *Nephtys coeca* of European waters. I have com

pared the Puget Sound specimens with some in the Museum of Comparative Zoology from Massachusetts Bay, and find them identical in every respect.

EUPHROSYNIDAE.

19. **Euphrosyne heterobranchia** sp. nov. Pl. 6, figs. 60-66 *a-c*.

Form elliptical, robust, slightly more tapering towards the posterior than towards the anterior extremity. Dorsal bare stripe narrow, less than one fourth the width of body. Somites, 34.

Caruncle (Fig. 60) low, bilobed dorso-ventrally, the lobes of equal length, reaching sixth somite. It has eight longitudinal ridges, two pairs in the upper, and two in the lower lobe, extending the entire length of the caruncle. Median tentacle short and awl-shaped, its filiform tip nearly as long as the thick basal portion; at its base the two posterior or "dorsal" eye-spots. The anterior or "ventral" eye-spots confluent, flanked on each side by a very minute antenna.

Palpi rather broad and flat, separated by a slight furrow from first and second somites, divided by a conspicuous median cleft. The mouth bordered posteriorly by the 5th somite.

Parapodia of usual form in this genus. A short ventral cirrus at posterior edge, adjacent to the intersegmental furrow; a lateral cirrus between the fourth and fifth gill-trunks, counting from the uppermost of the series; a stout, fusiform dorsal cirrus, not exceeding the branchiae. Branchiae ten on each side, some simply forked, others ramose, branching twice (Figs. 66 *a-c*). Setae all with hard, glistening tips; the bifid ones of dorsal series often have a very minute lateral tooth (Fig. 63); lateral tooth of ventral series also small (Fig. 65); cleft setae both serrate and non-serrate (Figs. 61-62*a*), the latter form the more common; serrations sometimes very few.

Length, 13 mm.; width, not including setae, 4.5 mm.; dorso-ventral thickness, 33 mm.; median base stripe, 1 mm.

A single specimen in the Columbia collection. The species is interesting for its resemblance to *E. borealis* of the North Atlantic, as to the heterogeneous character and large number of its branchiae, but differs from it in the shape and multiform nature of its setae, and in the larger number of somites. It is sufficiently distinct from all other known species of our Pacific coast, although its superficial resemblance to *Euphrosyne arctia* is rather striking.

As regards the so-called "branchiae" of *Euphrosyne*, it was long ago pointed out by Claparède ('68, p. 420) that functionally these are no branchiae, but probably glands, which furnish the slime with which the animal is more or less coated. I have recently had an opportunity to examine these structures in a young specimen of *E. aurantiaca* and compare them with the functional branchiae of *Eurythoe californica*, both *in situ* and freshly abscised from the living animal. While the branchiae of *Eurythoe* are richly vascular, the organs of *Euphrosyne* show not the slightest trace of blood-vessels, although almost as transparent as those of *Eurythoe*. On the other hand, these gill-like structures are richly beset with glandular cells, and there cannot be much doubt that they furnish a part or the whole of the mucus with which the setae are usually enslimed. The relationship of *Euphrosyne* to *Eurythoe* is undoubtedly close; many authorities place them in the same family. We may therefore legitimately conclude that here we have homologous structures that have undergone a change of function; and the term "branchia," applied in a morphologic sense, is not a misnomer, although perhaps liable to be misleading.

Study of sections of specimens of *Euphrosyne aurantiaca* and *Eurythoe californica*, fixed in aceto-sublimate and stained with haemalum, shows less difference in the structure of the gills than would appear to exist from examination of the structures in the living or fresh condition. Both, indeed, contain blood-vessels or structures functioning as such. In *Eurythoe* the presence of a vascular loop is very evident, but in *Euphrosyne* I have not been able to detect a loop, or in fact anything more than a cleft in the tissue sometimes empty, sometimes filled with coagulum. This seems to be a lymph space connected with the body cavity. In both species the walls of the gills are thick, but thicker in *Euphrosyne* than in *Eurythoe*. The branchiae of *Euphrosyne* contain an axial strand of muscle fibres. Their surface is ciliated.

SYLLIDAE.

20. **Pionosyllis elongata** sp. nov. Pl. 6, figs. 67-70. Pl. 7, fig. 71.

Form slender, becoming much elongated with age; 140-200 somites; diameter nearly uniform the entire length, tapered slightly towards head and tail; intersegmental furrows are deeply incised; somites average two and one half times as broad as long.

Prostomium (Fig. 67) about one and one half times as broad as long, in front obtuse, convex, the base nearly full width of peristomium. Palpi fused for nearly half their length. Antennae and median cirrus moniliform, similar to peristomial and dorsal cirri. Eyes four, the anterior pair twice the size of the posterior, and considerably further apart.

Peristomium with dorsal and ventral cirri, without parapodia or setae.

Parapodia (Figs. 67, 69) uniramous, with double aciculae; setae few; ventral cirri short, plain; dorsal cirri moniliform, gradually tapered from the base; slightly exceeding in length the diameter of the worm. Articulations 10-15 in antennae and peristomial cirri, increase to 16-18 (in some specimens, 18-20) in dorsal cirri of the anterior region, then diminish to 14-15 in more posterior somites.

Pygidium (Fig. 68) hemispherical; anus on its dorsal side; anal cirri longer than the dorsal cirri, cylindrical, 16-17 jointed.

Alimentary canal (Fig. 71) of usual form; proboscis with a circlet of thirteen conical papillae (*pap.*) at its orifice, and armed with a single tooth (*t.*) near anterior edge of chitinized lining; proboscis frequently found everted in preserved specimens. Oesophagus (*oes.*) elongated, extending through about twelve somites; its posterior third thick-walled and glandular. The proventriculus or "gizzard" (*prov.*) of the usual structure, extending through eight to ten somites, according to degree of contraction of body; cylindrical, rounded at the ends, lumen very narrow. Ventricular coeca (*c.*) much elongated, extending through four somites, frequently curved or bent double and opening into digestive tube just back of the proventriculus.

Sexes distinct; no stolonization; genital products develop only in posterior somites (163d to 194th in a female specimen with 198 somites), which become much enlarged in consequence.

Color, in life, nearly white, translucent; ova rich yellow.

Length of full-grown female (198 somites) 58.5 mm.; transverse diameter, including parapodia, 1.1 mm.

A single specimen was collected by Miss Robertson at Port Orchard in July, 1899. It is immature, measures 31 mm. in length, and has but 146 somites.

This species occurs within tide-marks as far south as Pacific Grove, Cal., where I have taken sexually mature specimens in December. I have also collected, in the month of February, sexually

mature specimens of exceptionally large size at Point Cavallo, on the northern shore of the Golden Gate, where it occurs in small numbers on the underside of stones, inside of dead shells, etc. The much-swollen caudal segments, turgid with ripe ova, are very conspicuous.

I have examined the radial muscle-columns in the proventriculus, and find the structure as regards the central core of granular, undifferentiated protoplasm, in which the nuclei are located, and as regards the peripheral layer of muscle tissues, in harmony with the statements of Haswell ('86) and Malaquin ('93); I have not, however, been able to discern striations in the muscular part, but this may be due to the fact that the material was not preserved with a view to histological study.

21. ***Trypanosyllis gemmipara*** sp. nov. Pl. 7, figs. 72-76.

Form elongated, much flattened dorso-ventrally, tapered towards both ends, abruptly towards the head, gradually towards the pygidium; somites very short; parapodia less than one sixth the width of the trunk in its widest portion; somites very numerous (300 or more).

Prostomium (Fig. 72) comparatively small, broadest in front, distinctly bilobed, the lobes separated by a median furrow; eyes four, the anterior pair larger and very slightly further apart than the posterior. Median cirrus nearly twice as long as the antennae; these, as also the peristomial cirri and all the dorsal cirri, moniliform, with numerous short articulations, diminishing in size towards the tip. Entire surface of cirri covered with dark brown, easily detached, bud-like bodies (Figs. 72 and 74). Palpi (*p.*) reniform, elongated, projecting far in front of the prostomium, widely separated their whole length.

Peristomium extremely short, embracing the prostomium on its two sides; bearing at its anterior corners two pairs of forwardly directed peristomial cirri, of which the dorsals are twice the length of the ventrals. The arrangement of prostomium and peristomium, together with their appendages, closely resembles the collocation of these parts in the Polynoids.

Parapodia (Fig. 74) not prominent, ventral ramus fairly developed, pointed at tip, with 7-9 setae of the form shown in Fig. 75; a small separate lobe covers the tips of the double aciculae. Ventral cirrus (*v. c.*) short, often curved, blunt at tip, non-moniliform. Dorsal cirrus very long, either straight or circinate at tip; in the

latter case incurved over the dorsum, in the former extending nearly at right angles to longitudinal axis of the body.

Digestive system exhibits a well-developed trepan (Fig. 73) of ten teeth; these are surrounded by a circlet of elongated papillae (*pap.*). Oesophagus of moderate length (extending through 22 somites), strongly chitinized; proventriculus cylindrical, of uniform diameter throughout; two well-defined lateral raphes; radial muscle-columns very large. Alimentary canal back of proventriculus with extensive, segmental, paired diverticula.

Dorsal surface elegantly marked with fine transverse dark lines which indicate the boundaries of the segments.

Posterior extremity capable of producing successive crops of collateral, sexual buds or zooids (Fig. 76), which possess every external structure of the parent except mouth and anus. They lack, however, an alimentary canal and nephridia.

Length, 68 mm.; transverse diameter, 3 mm.; dorso-ventral diameter, 1 mm.

A single specimen was collected by the Columbia University expedition, probably in the vicinity of Port Townsend. Unfortunately, no data accompany it. This individual possesses the remarkable sexual zooids, over fifty in number, presenting all stages of development. They arise as collateral buds from a proliferating somite near the posterior extremity (Fig. 76). At full maturity they evidently separate from the asexual stock and become free-swimming sexual zooids, provided with parapodia, antennae, eyes, and central nervous system, but destitute of an alimentary canal. They will be fully described in volume 2 of the Biological Bulletin.

ONUPHIDIDAE.

22. *Northia elegans* sp. nov. Pl. 8, figs. 77-85.

Form stout, flattened dorso-ventrally, tapering towards head; except in most anterior region, dorsal contour flattened and ventral convex; branchiae simple, filiform, upraised, and slightly incurved over the back.

Prostomium (Fig. 77) small, conical, considerably broader than long, and its surface monopolized by its large appendages; three pairs of antennae; most anterior pair short, ovoid; second pair with annulate basal joints and acute terminal joints about one half the

length of the basal joints; third pair three-jointed, the middle joint much the shortest, and the distal twice as long as the proximal; this pair more than twice as long as the second pair, and reaching the sixth somite. Basal joints of second and third pairs of antennae with nine or ten obscure annulations. Median cirrus likewise three-jointed, one half as long as third pair of antennae, and with long terminal stylode; its basal joint five-annulate. Palpi large, globose, approximate (Fig. 78, *p.*). Eyes four, small, at bases of third pair of antennae, one pair directed forward, the other laterally (Fig. 78).

Peristomium (Fig. 77, 78) shorter and narrower than the other somites, having on its antero-dorsal border a pair of small, slender, peristomial cirri (Fig. 78, *p. c.*).

Somites: first four or five back of peristomium longer and narrower than the succeeding ones, with parapodia (Figs. 77, 80) of different form from the rest, characterized by an elongated ventral ramus, with acute achaetous terminal portion, a large fusiform ventral cirrus (*v. c.*), a dorsal cirrus (*d. c.*) of similar form and dimensions, and a cirriform gill (*br.*), likewise of similar aspect. The transition to the typical somite and foot is gradual (*cf.* Fig. 81, 28th foot).

Branchiae unbranched throughout, tapered to an acute tip, increasing in length caudad, until they exceed half the transverse diameter of the trunk. The setae of the 4-5 anterior parapodia are different from those of the succeeding feet, and are of two forms, "hooded crotchets" and capillary bristles (Figs. 82, 83). Setae of dorsal rami throughout the series are buried in the foot; at most, their tips protrude (Fig. 85). Setae of ventral rami beyond fifth foot are (1) bordered capillary (Fig. 84), (2) a pair of stout, two-pronged uncini with flabellar expansions at tip — in all respects like uncini of succeeding species (Fig. 90).

Upper jaws (Fig. 79) asymmetrical, six pieces on right, seven on the left.

Length of 85 somites, 66 mm.; transverse diameter, 6 mm.

The antero-dorsal portion of the trunk elegantly marked with paired umber-brown spots placed near the posterior border of each somite; these tend to coalesce across the median line (Fig. 77).

Three or four specimens of this fine *Northia* occur in the Columbia University collection. Unfortunately, all lack the posterior portion of the trunk. There are no data as to depth or exact locality. The tubes also are lacking.

23. ***Northia iridescens*** sp. nov. Pl. 8, figs. 86, 87. Pl. 9, figs. 88-92.

Form slender and nearly cylindrical, of almost uniform diameter in anterior region; highly iridescent; branchiae curved over dorsum, not reaching median line; slender, filiform, translucent (Fig. 88).

Prostomium (Figs. 86, 88) small, hemispherical; first or "accessory" antennae elongate ovate, constricted at base; second pair of antennae two-jointed, basal joint slightly the longer, twelve-ringed; third pair of antennae three-jointed, with 11-13 annulations; this pair nearly four times as long as the second pair. Median cirrus a little shorter than third pair of antennae; nine-ringed. Eyes wanting. Palpi (Fig. 86) globose, pedunculate, spreading.

Peristomium much broader than prostomium, with a pair of minute peristomial cirri (Fig. 88) projecting from its anterior border.

Jaws (Fig. 87) very similar to those of *N. elegans*, but with more teeth on the dental plates and more slender maxillae.

Somites: four following the peristomium with modified parapodia (Fig. 88), similar to the same somites in *N. elegans*; the succeeding ones with filiform gills and dorsal cirri, but no ventral cirri (Fig. 89).

Hooded crotchets (Fig. 91) of ventral fascicles of first four somites very similar to those of preceding species. Two stout, wing-tipped uncini (Fig. 90) in ventral fascicles of parapodia further back. Capillary setae with striated border (Fig. 92).

Length of 52 somites, 38 mm.; transverse diameter, 3 mm.

This species is represented by a single specimen, dredged by Prof. W. A. Herdman at Victoria, B. C., in the summer of 1897, and by him kindly placed in my hands for description. Unfortunately, all the posterior portion of the specimen is lacking. The tube is of parchment-like material, opaque-white, flexible, and with adherent sand-grains.

LUMBRICONEREIDAE.

24. ***Lumbriconereis zonata*** sp. nov. Pl. 9, figs. 93-100.

Form cylindrical, slightly tapered towards anterior end; parapodia placed a little below the mid-lateral line; somites three times as broad as long, each marked with a sharply-defined brown zone

which extends around the trunk, widening on each side, above and below, as it approaches the parapodium. Middle of each band marked by a sharp dark line (Figs. 93, 95, 96).

Prostomium (Fig. 93) acorn-shaped, of a lighter tint than the trunk; perfectly smooth and glistening.

Peristomium (Fig. 93) tapered to the diameter of the base of the prostomium which is less than three fourths the diameter of the third somite. Second somite about one half the average length of the somites.

Jaws as shown in Fig. 94.

Parapodia (Figs. 97, 98) less than one half diameter of body, bi-lobed at tip, posterior lobe the longer. Setae inserted between the lobes. Setae, as usual, of two forms: winged capillary (Fig. 99) in anterior portion of body and "hooded crochets" (Fig. 100) in the posterior portion.

Length of 200 somites, 167 mm.; diameter, including parapodia, 4.5 mm.; without parapodia, 3 mm.

A single imperfect specimen lacking the posterior region, was collected by Professor Ritter at Salmon Bay, Puget Sound, May 29, 1899. This specimen is remarkable for the possession of abnormal segmentation in as many as five places. In two instances the somites are spiral in the way shown in Figs. 95, 96, representing respectively the dorsal and ventral sides. In another place, the spiral extends through nine somites, with a forked somite at each extremity. The other two instances are partially-divided somites without a spiral arrangement—in one case with the parapodium displaced towards the ventral side. The asymmetrical somites are not confined to any limited region, but are scattered for a long distance through the middle region of the body.

GLYCERIDAE.

25. *Glycera rugosa* sp. nov. Pl. 10, figs. 101, 102.

Form stout, terete, thickest about one third the distance from head to posterior extremity, tapering slightly cephalad; much more, though gradually, caudad. Number of somites 200–300, distinctly two-ringed, all setigerous except the pygidium. The rings are nearly equal, but the anterior one, which bears the parapodia, is often raised like a welt, giving the body a corrugated aspect.

Prostomium conical, tapering, 2-3 mm. long, length exceeding its breadth, obscurely twelve-ringed; four minute tentacles at tip. Basal portion not sharply set off from the peristomium. Palpi (?) retracted.

Pygidium small, globose, bearing a pair of slender subulate anal cirri. Anus minute, on dorsal side of pygidium.

Parapodia (Fig. 101) stout, of nearly equal height and length, the largest equal to width of dorsum in its widest part; except the two most anterior pairs, four-lobed, the two anterior lobes slightly longer than the posterior, but all lobes of nearly same form except in most anterior parapodia. Anterior dorsal lobe sometimes bifid. All the lobes more or less conical and pointed; their tips darkly pigmented; simple capillary setae inserted between the dorsal lobes; the compound setae between the ventral. Ventral cirrus (*v. c.*) large, conical, strongly resembling the lobes; dorsal cirrus (*d. c.*) smaller, globose, much constricted at the point of attachment, placed high, at the base of the parapod.

Branchiae (Fig. 101) begin at the 16th or 17th parapod and extend to the 22d from the pygidium; they consist of eight or nine finger-like, thin-walled lobes, sometimes bifurcated; completely retractible into body-wall; at sexual maturity crowded with reproductive cells (Fig. 101). *All branchiae are on posterior aspect of the parapodium*; the most anterior and most posterior of the series are single, sausage-shaped processes.

Proboscis extremely variable in length (12 to 35 mm. or more), club-shaped, thicker than anterior portion of body, beset with minute papillae of two forms, conical and ovate. Jaws (Fig. 102) strongly hooked; each bears a triangular appendage (*ap.*) with long falcate process.

Color of alcoholic and formalin specimens variable, from tawny or buff to olive-brown. The color is due to abundant yellowish brown pigment grains in the hypodermis. These are often aggregated towards tips of the lobes of the parapodia.

Length of large specimen (much contracted), 170 mm.; transverse diameter, including parapodia, 9 mm.

This species is probably abundant in the Puget Sound region, as it occurs in all the collections. It has been taken at Neah Bay, and at Salmon Bay (near Seattle); and there are a considerable number in the Columbia collection (probably from the vicinity of Port Townsend) for which no locality is given. A Glycerid col-

lected by J. K. Lord at Esquimalt and described under the name *Glycera corrugata* by Baird ('63) is probably identical with *G. rugosa*, but the description is too meager to admit of positive determination. Many of the larger specimens are females with ripe or nearly ripe ova; but I have seen no specimen which has undergone the atrophy of the proboscis incidental to sexual maturity mentioned by Arwidsson ('98, p. 6).

As the Glyceridae are destitute of a vascular system, the gills are merely reversible pouches of the body-wall, into which the caelomic fluid passes. Reproductive cells also enter these thin-walled pouches.

26. ***Glycera nana*** sp. nov. Pl. 10, figs. 103, 103a.

Form short, thick, somites comparatively few (about 140 in one specimen); diameter nearly uniform for greater portion of length; somites two-ringed; the posterior ring slightly raised above the level.

Prostomium conical, ten-ringed, four minute tentacles at tip. Proboscis short, club-shaped, beset with conical papillae. Jaw-appendage as shown in Fig. 103a.

Parapodia (Fig. 103) rather slender, anterior lobes two, the ventral one the longer, both conical; posterior lobe single, rounded; ventral cirrus (*v. c.*) similar in shape to upper anterior lobe; dorsal cirrus a rounded tubercle placed high above the foot on the side of body; no gills.

Setae elongate, of the usual two forms, capillary dorsal, and compound ventral.

Length of larger specimen, 64 mm.; greatest transverse diameter, 6 mm.; without parapodia, 4 mm.

The species is present in the Columbia collection and also in Miss Robertson's; she obtained it at Port Orchard in July, 1898. The exact locality is not recorded for the other specimen. In both examples the posterior portion is regenerating, so it is impossible to give accurately the normal number of somites. It probably lies between 180 and 200.

27. ***Hemipodia borealis*** sp. nov. Pl. 10, figs. 104, 104a.

Form terete, moderately long and slender, of nearly uniform thickness for the greater portion of the length, but tapered posteriorly; somites three-ringed, 126 in number; two minute anal cirri.

Prostomium with conical, ringed process, tipped with four (?) tentacles. Proboscis beset with minute, ovate papillae. Jaws with notch near base; jaw-appendage (Fig. 104a) a simple rod.

Parapodia (Fig. 104), as invariably in this genus, with only the lower ramus, a single acicula, and no simple setae. The dorsal cirrus (*d. c.*) near the foot, ovate; no gills. Parapodia consisting of an anterior, elongated lobe and a posterior, short, rounded one.

Length, 72 mm.; transverse diameter, including parapodia, 3 mm.

Only a single female specimen of this very interesting species occurs in the Puget Sound collections. It was gathered by the Columbia University Expedition — exact locality not known. It contains large eggs, and is evidently mature.

The genus *Hemipodia* was established in 1865 by Quatrefages for the reception of a peculiar Glycerid from Chile, which he named *H. roseus*. The same year another species from the Straits of Magellan was described under the name *H. patagonica* by Kinberg ('65, p. 245). Until the present, no genuine species of *Hemipodia* has been added to the two original ones, although two species of Glyceridae — *Hemipodia* (?) *magellanica* M'Intosh ('85, p. 349) and *H. septentrionalis* Roule ('96, p. 452) — have been erroneously attributed to this genus (*vide* Arwidsson '98, p. '28).

ARICIIDAE.

28. *Scoloplos elongata* sp. nov. Pl. 10, figs. 105–110.

Form long and slender, somites short and very numerous (293 in one specimen); flattened anteriorly; broadest between 9th and 17th somites; thence narrowing gradually to a uniform diameter which is kept about as far as the 200th somite, thence gradually and uniformly diminishing to the slightly expanded, hemispherical pygidium. Dorsum plane, but apparently concave on account of the upward direction of the parapodia. Ventral aspect convex, flattest in the widened anterior region, where dorsal and ventral surfaces are nearly alike and the parapodia are laterally directed.

Prostomium small, tipped by a conical, acutely-pointed palpode (Fig. 105, *pp.*); without eyes.

Peristomium increasing rapidly in width towards the second somite, which is the first to bear setae. Pharynx eversible, with leaf-shaped lobes (Fig. 106).

Parapodia at anterior end (Fig. 107) with dorsal and ventral setae, and simple branchiae. Setae closely serrated (Fig. 109). Parapodia back of the anterior region (Fig. 108) with larger, ciliated

branchiae and dorsal cirri. Dorsal and ventral setae in small fascicles. Ventral ramus of foot continued ventrad as a leaf-like expansion, but not extending below the medio-lateral line. Anus on dorsal side of pygidium; anal cirri long and slender.

Length, 192 mm.; width of thorax, 3 mm.; width of abdomen (including parapodia), 2 mm.

This species burrows in sandy shores, near low-water mark, whereas the much commoner and more widely distributed species of *Aricia* found on the Californian coast has its habitat among the rhizomes of *Phyllospadix*. The present species is represented in the material from Puget Sound by a number of incomplete specimens collected by the Columbia University Expedition and by Miss Robertson.

LEVINSENIIDAE.

***Aricideopsis* gen. nov.**

Characters of *Aricidea* Benedict and Webster, but differs from it in having well-developed parapodia and setae on the peristomium, and no ventral cirri. Eyes very large, compound. Anal cirri, two.

29. ***Aricideopsis megalops* sp. nov.** Pl. 10, figs. 111, 112. Pl. 11, figs. 113, 114.

Form of moderate length, gradually tapering from the anterior to the posterior extremity, color of preserved specimen pale yellow, the dark intestine showing through in the posterior portion. Parapodia with distinct rami flattened into foliaceous expansions, much the largest dorsally, and in the anterior half of the body; setae in both rami; uncini and capillary setae in all ventral rami (except the last two or three, which are achaetous) back of the 18th.

Prostomium (Fig. 111), the full breadth of trunk, rounded anteriorly, elevated in a median thickening at base, which is bilobed anteriorly, and bears the median cirrus and the large crescentic eyes.

Parapodia (Figs. 112, 113) with dorsal rami expanded into leaf-like form on somites 2-24 and beyond, gradually becoming smaller and more rounded; towards end of series the upper lobe becomes minute; ventral lobe rounded, always smaller than the dorsal; a filiform gill (*br.*) on somites 2-27, often with lanceolate tip. Setae (Figs. 112, 113, 114) of two sorts: capillary and "hooded crotchets"; both kinds occur in the ventral rami back of the 17th somite; at

first only one or two uncini (Fig. 114) among the capillary bristles, gradually increasing to five, while the capillary bristles decrease *pari passu*. Anal cirri two, short and stumpy.

The present species undoubtedly belongs to the family Levinsoniidae recently established by Mesnil and Caullery ('98) for the reception of a small group of peculiar little Polychaetes which show affinities to the Spionidae on the one hand, and to the Ariciidae on the other. The species under consideration most nearly resembles *Aricidea*, of which two species have been described from the Atlantic coast by Webster and Benedict ('87). It differs enough however from *Aricidea* to deserve generic distinction. The presence of parapodia and setae on the peristomium probably indicates a more primitive character than the allied genus exhibits. The large size of the eyes is also remarkable, and would seem to indicate a pelagic habit.

The foregoing description is based upon a single specimen from Port Orchard, collected by Miss Robertson in June, 1899.

MAGELONIDAE.

30. **Magelona longicornis** sp. nov. Pl. 11, figs. 115-118.

Form cylindrical, rather stout, of nearly uniform diameter, divided into two regions: (1) the *anterior*, in front of ninth somite, with capillary, double-bordered setae (Figs. 115-117) in both fascicles; (2) the *posterior*, back of and including the ninth somite, with uncini (Fig. 118) both above and below. Ninth somite (Fig. 116) shorter than the others, and marked by a deeper constriction, with a pair of comb-like fascicles of short, stiff, capillary setae.

Prostomium (Fig. 115) flattened, grooved in median dorsal line, anterior tip expanded; no eyes. Peristomium bears a pair of enormously long, flexile, tentacular cirri, beset with numerous capitate papillae on exterior aspect; showing rings of contraction near its base (Fig. 115). Proboscis (*pr.*) rounded, without corrugations or surface differentiation; extensible as far as tip of prostomium.

Parapodia (Figs. 115, 116) of anterior region slightly developed; dorsal and ventral cirri small; a small branchia between them; dorsal and ventral setae (Fig. 117) of same form, double-bordered capillary. In posterior region, branchiae and cirri are larger; uncini (Fig. 118) in form of "hooded crotchets" bidentate at tip, in transverse rows of ten or eleven, rising high upon dorsal side.

Length of head and anterior region, 7 mm.; length of first 12 somites of abdomen, 8 mm.; greatest transverse diameter, 1.5 mm.; length of tentacular cirri, about 14 mm.

Two imperfect specimens, consisting of only a few anterior somites, represent this interesting species. It was collected by Miss Robertson at West Seattle, June 23, 1899.

Magelona papillicornis, originally described by Fritz Müller ('58) from the Island of Santa Catharina off the coast of Brazil, has since been found on both sides of the North Atlantic (*vide* Andrews, '91). Its anatomy, both external and internal, has been carefully studied by M'Intosh ('78) and its remarkable blood has been investigated by Benham ('96). Hitherto it has remained a unique and isolated form, most closely related to the Spionidae but, as M'Intosh pointed out, having affinities also with the Chaetopteridae. The present species differs from *M. papillicornis* (1) in its much greater size, (2) in the greater length of its tentacular cirri and longer papillate areas of same, (3) in the comparative shortness of the prostomium, and (4) in the smoothness of the proboscis.

CAPITELLIDAE.

31. *Capitella dizonata* sp. nov. Pl. 11, figs. 119-121.

Thorax thickest in region of 5th and 6th somites; smallest at 8th and 9th (Fig. 119), most of the thoracic somites two-ringed; abdominal somites three- to twelve-ringed; intersegmental constrictions pronounced, especially in thorax.

Prostomium short, conical, at base slightly more than one half the diameter of the peristomium; nuchal organs not discovered.

Peristomium setigerous; somites of thorax over three times as broad as long in the contracted state; the 4th and 5th each with a dark brown band passing around it in front of the fascicles. Female genital pore between the 7th and 8th somites (♀, Fig. 119).

Abdominal somites notably longer than the thoracic, beginning at the 10th, which differs but slightly from the 8th and 9th of the thorax; increase caudad in length and number of rings. Uncinigerous tori placed near the posterior boundary of each segment; the ventral the first to appear, and larger than the dorsal throughout anterior region of abdomen.

Capillary setae (Fig. 120) alone present in first seven segments; obtusely angled, with striated limb on convex border, arranged in dorsal and ventral widely separated fascicles; persist in dorsal fascicles as far as 10th somite; beyond this point replaced entirely by uncini.

Uncini (Fig 121) begin in ventral fascicles at 8th somite; in dorsal fascicles at the 10th; hooded, with four minute teeth above rostrum; shaft strongly geniculate.

Length of 39 anterior somites, 36 mm.; greatest transverse diameter of thorax, 1.5 mm.

This species is represented in the collection by a single incomplete specimen, lacking the posterior portion. It is an immature female, and was collected by Miss Robertson at Port Orchard, July 2, 1898. The dorsal setae of the 8th and 9th somites appear to be entirely wanting.

CHLORAEEMIDAE.

32. *Trophonia papillata* sp. nov. Pl. 12, figs. 122, 123.

Form rather long and slender, slightly tapered, thickest anteriorly, abruptly diminishing toward mouth; subcylindrical; intersegmental constrictions distinct, but not noticeably deepened caudad; entire surface papillate, slightly rough to the touch, but without adherent sand-grains; dorso-ventral differentiation slight, mainly expressed in differences between dorsal and ventral setae, and in the closer papillation of dorsum.

Oral tentacles (Fig. 122) eight, of moderate length, pointed at tip; palpi (*p.*) thicker and blunter, grooved on ventral aspect, distinctly constricted at regular intervals.

Setae of second, third, and fourth somites, both dorsal and ventral, elongated, flexible, capillary bristles, forwardly directed (Fig. 122), exhibiting the usual transversely-striate structure. Dorsal setae of remaining somites, capillary, three or four to each fascicle; ventral setae (uncini), to the same number; stouter than dorsal setae, blackish, hooked (Fig. 123).

Somites of only complete specimen, 89 in number; those in the anterior region twice as broad as long; posteriorly, length and breadth gradually becoming equal.

Length, 88 mm.; greatest transverse diameter, 4 mm.

Two specimens, one incomplete, were collected at Port Orchard, July 2, 1898, by Miss Robertson.

33. **Flabelligera infundibularis** sp. nov. Pl. 12, figs. 124-127.

Form (Fig. 124) rather stout, squarish, dorsal aspect more flattened than the ventral; enclosed in clear mucus; tapered in posterior third to a minute caudal extremity; oral region (2d somite?) flared, with an almost complete circle of setae on the margin, formed by two broad fan-shaped fascicles; intersegmental constrictions deep; parapodia (Figs. 124, 126) well developed, distinctly biramous, on every somite from the third.

Peristomium within the oral funnel; bears numerous slender tentacles and two stout, lobulated palpi (*p.*).

Dorsal setae (Figs. 125, 126) longest and most numerous on second somite, where they form the funnel; on the other somites, more slender, delicately curved, completely imbedded in the jelly, transversely striate. Ventral setae (Fig. 126) begin on third somite, one or two in each ventral ramus, in form of long hooks, transversely striate, blackish towards tip. Numerous sensory papillae (Fig. 127) are borne at the tips of long varicose pedicels.

Somites in four specimens are 42, 50, 56, and 71, increasing in number with size of animal. In contraction, somites are at least four times as broad as long.

Length of specimen with 56 somites (about average size), 55 mm.; greatest transverse diameter, 5 mm.

According to the statements of Harrington and Griffin ('97, p. 162), this species is enormously abundant in Scow Bay, where it covers the muddy bottom over an area about half an acre in extent. The depth given for one lot of specimens is six fathoms. It does not appear in any of the littoral collections from the region of Seattle.

The extraordinary elongation of the dermal sensory papillae in species of this genus is well exemplified in the present form. The thick coating of mucus which envelops every part of the animal except the anterior and posterior extremities (Fig. 124) (the funnel formed by the broad flabellate oral tentacles makes a passage to the mouth) apparently renders necessary this method of putting the animal in communication with the outer world.

STERNASPIDAE.

34. *Sternaspis fossor* (?) Stimpson.

Three specimens, apparently of this species, were collected at Victoria, Vancouver Island, by Prof. W. A. Herdman. The specimens are not sufficiently well preserved to admit of thorough and critical study; but comparison of the ventral shields with those of a specimen of *S. fossor* from the Atlantic coast, and also with Marenzeller's ('90) figures, makes it reasonably certain that the above identification is correct. Specimens from Puget Sound collected by the naturalists of the Northwest Boundary Commission were doubtfully described by Stimpson ('64) as a new species, which he named *Sternaspis affinis*.

MALDANIDAE.

35. *Clymenella*¹ *rubrocincta* sp. nov. Pl. 13, figs. 128-133.

Form considerably elongated, cylindrical, narrowed in region of third and fourth somites, gradually enlarging to maximum diameter in region of somites 10-12, thence narrowing to somites 15-17, which are the longest and slenderest of the body; the remaining somites (18-22) slightly thicker and progressively shorter; the 21st the shortest of the body.

Cephalic plate (Figs. 128, 129) oval, concave on dorsal side, nearly bisected longitudinally by a median ridge continued back from the ovate palpode; a distinct raised margin, and well-developed longitudinal nuchal organs (Fig. 129, *n. o.*). Mouth with thickened corrugated lower lip and crescentic outline.

Peristomium achaetous; capillary setae and uncini begin on second somite (Fig. 128), the latter with scarcely perceptible tori at first; tori become distinct in fourth somite; dorsal setae from wart-like papillae.

Somites gradually increasing in length from fifth onward; fifth to eighth marked with a broad indian-red band back of the setae and uncini, accentuated by a narrower whitish band in front.

¹ *Axiotea* and *Clymenella* cover species too nearly alike to require generic distinction. As recently pointed out by Verrill ('00, p. 657), the name *Axiotea* being preoccupied, *Clymenella* (*sensu ext.*) should cover the species formerly included under *Axiotea*.

Tori much enlarged in somites 12-21. Last 3 somites (including pygidium) achaetous; pygidium funnel-shaped with cirrose border. Perianal cirri (Fig. 130) 18-30 in number, alternately long and short; the mid-ventral one much elongated, and containing prolongation of the ventral nerve-cord; tips of all the longer cirri recurved. Anal rosette with alternate sectors raised, corresponding in position with the longer cirri.

Capillary setae of two forms, bordered and serrated, the latter much the more slender (Fig. 133). Both kinds in same fascicle; begin at second somite. Uncini (Figs. 131, 132) with five or six teeth, including rostrum, graduated in size; bristles at base of rostrum lateral in position.

Length of large specimen, 162 mm.; greatest transverse diameter, 3.5 mm.

This fine species comes near *Axiothea catenata* Malmgren, a form of wide distribution in the North Atlantic and Arctic, and reported from Bering Sea by Marenzeller ('90). The present species, however, differs from it in the form of the serrated setae and of the uncini. In *A. catenata* there are four preanal achaetous somites, in the present species only two; *C. rubrocincta* has 22 segments; *A. catenata*, 24.

The present species was collected both by the Columbia University Expedition and by Miss Robertson. I have found it in abundance at the entrance of Tomales Bay, and at San Pedro, California. It forms a tube of coarse sand, which is lined by a peculiarly tough, opaque, whitish membrane.

36. **Nicomache personata** sp. nov. Pl. 13, figs. 134-139.

Size small; 25 somites, of which all except the peristomium and the last two are setigerous; no cephalic plate; prostomium and peristomium united to form a hood-shaped head (Fig. 134); mouth large, overhung by projecting upper lip; a distinct crease in peristomium back of mouth.

Somites increasing in length back of second; longest from the 8th to the 17th; those at the end very short; pygidium (Fig. 135) funnel-shaped, with a zone of 16-18 cirri on margin, quite uniform in length. Dorsal and lateral surfaces of head and first four or five somites beautifully mottled with chocolate-brown; ground-color, white; somites 2-5 with contrasting white and brown bands; on the head these bands have the aspect of a grotesque face.

Setae of five kinds: (1) capillary double-bordered setae in all

somites from second to twenty-third; (2) smaller serrated setae together with (1) in dorsal rami; (3) ventral setae in first three setigerous somites in form of a stout, acute spine (Figs. 134, 136); (4) very long, filamentous, spiral setae in dorsal rami beginning at 7th to 11th somites and continuing to 23d somite (Fig. 138); (5) uncini (Fig. 137) of the usual form in this family, in all setigerous somites back of the 4th.

Length of much-contracted specimen (impossible to measure accurately on account of twists and flexures), 50 mm.; diameter through thickest portion, largest specimen, 1.75 mm.

The only specimens of this odd little species were collected by Miss Robertson at Alki Point, Aug. 3, 1898. The species bears a close superficial resemblance to *Nicomache lumbricalis* (Sars) Malmgren, but has one achaetous somite in front of the pygidium instead of two.

The long, silky, spiral filaments shown in Fig. 138 have not, I believe, been hitherto described in any Maldanid. Whether they are permanent structures peculiar to this species, or "nuptial setae" (Pubitåtsborsten) which develop only at sexual maturity, is an interesting question. Filamentous nuptial setae of a similar form have been described by Michaelsen ('92, p. 6) in a Polynoid (*Drieschia pelagica*).

AMMOCHARIDAE.

37. ***Ammochares occidentalis*** sp. nov. Pl. 14, figs. 140-142.

Form cylindrical, tapering towards posterior end; 23 (?) somites, of which 20 are setigerous.

Peristomium produced into ten thick, bluntly-ramose "tentacles" (Fig. 140) which rise to a level, giving anterior end of body a truncated appearance. Capillary setae in fascicles placed high on dorsal surface (Fig. 142), very slender, acutely pointed, silvery by reflected light, serrated. Uncini very minute, two-hooked (Figs. 141 a, b), 16-18 horizontal rows in each band (6th somite), extending three quarters of the way around the body; begin at 4th somite.

Second and third *somites* (Fig. 140) very short, third twice the length of the second, both with rudimentary parapodia (?). Somites 4, 5, 6, 7 the longest of the body; from the 7th diminishing gradually to end of series.

Length, 22.5 mm.; greatest transverse diameter, 1 mm.

No species of *Ammochares* has hitherto been reported as having chelate or bifid uncini. This character in fact has been considered so diagnostic of the allied genus *Myriochele* that M'Intosh did not hesitate to describe a species in the "Challenger" collection as *Myriochele pacifica* from a fragmentary specimen lacking both anterior and posterior extremities — basing his diagnosis entirely on the structure of the uncini.

The two specimens upon which the foregoing description is based were collected by Miss Robertson at Port Orchard, July 2, 1898. Each was enclosed in a tube composed of sand-grains and minute particles of shell. The color of the formalin preserved specimens is nearly black.

ARENICOLIDAE.

38. *Arenicola claparedei* Levinsen. Pl. 14, figs. 143, 144.

In the excellent memoir of Gamble and Ashworth (:00) upon the Arenicolidae, the Mediterranean species, originally described by Claparède ('70, p. 300) as *Arenicola marina*, but afterwards erected as a separate species by Levinsen ('83, p. 137, footnote) under the name of *A. claparedei*, is attributed to the Pacific coast. After a careful examination of the Puget Sound *Arenicolae* at my disposal, and comparison with specimens of *A. claparedei* from Naples, I am convinced that Messrs. Gamble and Ashworth are correct in their determination. The only notable points of difference between the Puget Sound specimens and those from Naples are the vastly greater size — at least eight times as great — of the former, and the smaller number of oesophageal coeca or "pouches" in the latter. Of the four specimens of *A. claparedei* from Naples which I have examined, three have four pairs of pouches, and one only three pairs; whereas, out of eight specimens from Puget Sound in four there are six pairs, in two fifteen pairs, in one sixteen pairs; and in one there are sixteen coeca on the right and eighteen on the left!

In the Arenicolidae there are as a rule only two oesophageal coeca or "pouches," but in *A. claparedei* they are not only numerous (as many as 32 in one instance, Fig. 144) but highly variable as to number and arrangement, and probably even differ as to function, if it is permissible to draw such an inference from the great size and thin-walled character of the most anterior pair (Figs. 143, 144).

As, however, the whole question of the structure and function of the oesophageal pouches of *Arenicola* is still unsolved, this problem must be deferred for the present.

The discovery of this Mediterranean form upon the Pacific coast of North America, and at no intermediate point, is certainly one of the most remarkable cases of discontinuous geographical distribution ever recorded.

With exception of a single specimen collected by Miss Robertson, I am indebted to Dr. C. M. Child of the University of Chicago for all the Puget Sound *Arenicolae* I have. The specimens were collected by the Columbia University Expedition — exact locality not stated.

While, as von Marenzeller has suggested, it is probable that Murdoch's ('84) *Arenicola glacialis* from arctic Alaska is none other than the circumboreal and widely-ranging *A. marina*, it is not at all certain that the latter species occurs so far south as Puget Sound, although it has been reported from Vancouver Island by von Marenzeller ('87).

CIRRATULIDAE.

39. *Cirratulus cingulatus* sp. nov. Pl. 14, figs. 145–148.

Form stout, size moderate, tapered at both extremities, decidedly flattened on ventral aspect; dorsum rounded; seven anterior somites without setae or cirri; two clusters of 17–18 tentacular filaments (Fig. 145, *t. f.*) each, on dorsal aspect of 8th (the first setigerous) somite; when removed, an oval transverse scar is left; a series of similar cirri along each side, in the anterior and middle portions of body inserted low (Fig. 146), gradually rising to a higher level in the posterior region.

Somites very short, three-ringed above the dorsal setae, the middle ring raised welt-like above the level (Fig. 146).

Prostomium (Fig. 145) acute, concave on ventral side towards mouth, which usually exhibits a partially everted pharynx; eyespots five or six, either in a group or transverse row.

Parapodia slightly developed (Figs. 145, 146), both dorsal and ventral rami with slender, serrated setae (Fig. 147); these alone are present for 30 setigerous somites back of the head; the uncini appear in the ventral rami (Fig. 148) at this point, and in the dorsal rami a few somites caudad; they continue to end of series.

Cirri, especially those of the first cirriferous somite ("tentacular filaments") of great length, frequently forming a tangled mass nearly as long as the entire body. Anus in pygidium, minute.

Length of large specimen, 100 mm.; greatest transverse diameter, 5 mm.

There are several specimens in the Columbia University collection, obtained "between tides." I have not found this species on the California coast.

40. ***Cirratulus robustus*** sp. nov. Pl. 14, figs. 149, 150.

Form short and thick; ventral aspect broadly flattened, concave anteriorly and posteriorly; dorsum rounded, tapered about equally towards both ends; 112 somites in one specimen, *not divided into rings* (Fig. 150).

Prostomium (Fig. 149) shorter and thicker than in preceding species; eye-spots in two oblique rows. First three somites achae-tous, fully twice the length of the rest; fourth with two clusters of tentacular filaments and with dorsal and ventral setae (Fig. 149, *t. f.*).

Parapodia (Figs. 149, 150) slightly developed; anteriorly with capillary setae alone; at the 19th or 20th somite the ventral uncini begin, and two or three somites further back, the dorsal; cirri inserted low in anterior somites (Fig. 149), gradually rising to mid-lateral line (Fig. 150) towards middle of length, then in posterior region gradually approaching the dorsal setae. Anus terminal.

Length, 59 mm.; greatest transverse diameter, 5 mm.

Only two mature and one young specimen of this species are available for description. One adult specimen was obtained at Neah Bay by the Columbia University Expedition; the other at Port Orchard by Miss Robertson. Both lack the cirri. The setae and uncini of this species are practically identical with those of *Cirratulus cingulatus*.

AMPHICTENIDAE,

41. ***Pectinaria brevicoma*** sp. nov. Pl. 15, figs. 151-156.

Form conical, gradually widening towards anterior end; cephalic disc nearly flat, plane, its edge entire; scapha broadly ovate, not wider transversely than posterior end of thorax. Total number of somites, about 27; 21 in thorax (of which 17 are setigerous, and 13 are uncinigerous), and 6 (?) in scapha.

Prostomium expanded into a large velum (Fig. 151) with 33 fimbriae on edge.

Peristomium with a pair of subulate, moniliform cirri and numerous club-shaped tentacles (much contracted in preserved specimens). Paleolae short, stout, arranged in two distinct groups, 10–12 in each; highly iridescent, either blunt or acutely pointed (lateral ones), strongly sloped towards ventral aspect. *Second somite* with a pair of cirri in all respects like the peristomial.

Branchiae pectinate, borne on third and fourth somites.

Setae broadly limbed and twisted near tip (Fig. 152) with serrations beyond the twist, or straight and without serrations (Fig. 153). The latter are not so numerous. They diminish in size towards anterior and posterior extremities of thorax. Uncini with 4 teeth (Fig. 154) or occasionally five (Fig. 155); the latter begin about the 11th somite; none were found in front of this. Spines on scapha (Fig. 156) with a stout, laterally-bent hook at tip.

Tube composed of coarse sand-grains, curved.

Length of largest specimen, 28 mm.; diameter of disc, 5 mm.

Several specimens were dredged by the Columbia University Expedition at a depth of 10 fathoms.

This species comes nearest to *P. (Cistenides) granulata* (Malmgren), which has been found in Bering Sea (Marenzeller, '90), and was collected at Kadiak by Mr. Cloudsley Rutter, differing from it only in the shortness of the paleolae and in the form of the setae and uncini. Upon examination of more abundant material, this form may prove to be identical with *granulata*, which is a wide-ranging, circumboreal species, and may therefore prove to be variable. While the uncini afford, on the whole, the surest diagnostic characters, they should be used with caution, as their variability in the present species clearly indicates.

AMPHARETIDAE.

42. *Sabellides anops* sp. nov. Pl. 15, figs. 157–161. Pl. 16, figs. 162–163.

Form stout, curved, thickest about midway of thorax, abdomen rather rapidly tapered, convex on dorsal, flat on ventral aspect (Fig. 157). Thirty to thirty-one somites, sixteen in thorax, fourteen to fifteen in abdomen; fourteen setigerous somites in thorax;

setae begin at third somite and cease at sixteenth. Uncini begin at sixth somite (the third setigerous somite), and extend to the pygidium. Dorsal rami of all abdominal parapodia destitute of setae and uncini.

Prostomium (Figs. 158, 162, 163) broadly truncated with two antero-lateral lobes; no eyes; a pair of transverse slits containing the nuchal organs at its base.

Peristomium (Figs. 158, 162, I) forming, with second somite, a region destitute of parapodia and branchiae. The club-shaped tentacles, about fifteen in number, arise from the inner border of the peristomium; they are destitute of papillae, but in contracted state are wrinkled (Fig. 163).

Branchiae, four on each side, smooth, terete, subulate, arise from dorsal aspect of the third, fourth, and fifth somites; in length about twice the diameter of the body (Figs. 158, 162).

Ventral *rami* or *tori* (Fig. 157) spatulate, increasing from the fourth somite to the sixteenth, thence diminishing to end of body. Each bears a single row of pectinate, six-toothed uncini (Fig. 161). Dorsal thoracic rami contain fascicles of single and double-bordered, straight and slightly-curved setae (Figs. 159, 160); dorsal rami achaetous throughout the abdomen.

Length of largest specimen, 27 mm.; greatest transverse diameter of same, 5 mm.

Several specimens are in the Columbia University collection, without data as to depth and locality. No tubes were preserved.

This species comes close to *Sabellides* (*Amage*) *auricula* (Malmgren) but differs from it in having longer branchiae, attached to three somites, shorter tentacles, and differently shaped uncini. *Sabellides auricula*, however, has been reported from Japan by Marenzeller ('85), and its occurrence in any part of the North Pacific would therefore not be surprising.

I follow Théel ('79) in discarding Malmgren's genus *Amage*, as not being sufficiently distinct from *Sabellides*.

TEREBELLIDAE.

43. ***Amphitrite robusta*** sp. nov. Pl. 16, figs. 164-168.

Form short, robust, thickest anteriorly in region between 5th and 12th somites, gradually and almost uniformly tapering thence to

posterior end. Total number of somites, 63-90; in thorax, 20, of which 17 (4th to the 20th inclusive) are setigerous. Uncini begin at 5th somite and extend to the penultimate. Uncini uniserial anterior to the 11th somite, and posterior to the 20th; biserial on thoracic somites 11-20 (Fig. 167).

Prostomium with dorsal ridge and small lateral lobes formed by its continuation to the sides; no eyes. Peristomium bearing a semicircle of tentacles, rather thick in formalin specimens, decidedly grooved, spirally coiled in contracted state, and about one half the length of the thorax. Peristomium forms a thick prominent ventral lip, opposable to thin ventral edge of prostomium.

Branchiae (Fig. 164), three pairs, on somites 2-4, densely ramose, di- and tri-chotomously branched; the main stems short and thick, ultimate branches subulate, slightly moniliform. Branchiae all nearly alike in form and size; anterior pair slightly the largest; all variable as to size and amount of branching.

Setigerous lobes moderate, increasing in size from the first to the seventeenth (on 20th somite). Uncinigerous tori of nearly uniform length from 5th to 18th somites; thence gradually diminishing to end of body.

Setae with striated limb on each side and curved, serrated tip (Fig. 165). Uncini avicular, with from 5 to 7 rows of teeth above the rostrum (Figs. 166-168).

Nephridial papillae twelve pairs, on somites 4 to 15; first pair considerably the largest; the rest of nearly uniform size; placed ventrad, and a little posterior to setigerous lobes.

Length of larger specimen, 75 mm.; greatest transverse diameter of thorax, 11 mm.; average transverse diameter of abdomen, 4 mm.

Several specimens, collected both by the Columbia University Expedition and by Miss Robertson. The species is doubtless common. No tubes were preserved. The absence of eyes in this species and in the preceding is remarkable. They are evidently wholly lacking, as I was unable to find them even in serial sections.

44. ***Amphitrite spiralis*** sp. nov. Pl. 16, figs. 169-171c.

Form greatly elongated, abdomen slender, terete, and spirally coiled when out of the tube; dorsal aspect of thorax high-arched; ventral slightly convex. This condition is enhanced in anterior portion of abdomen, where the somites are decidedly thicker on the dorsal than on the ventral aspect, producing thereby the spiral

coiling. Number of somites approximately 170; those of posterior portion of abdomen two-ringed. Thoracic somites, 43, of which 41 are setigerous and 39 uncinigerous.

Prostomium with dorsal crescentic groove separating a dorsal ridge from the ventral flap; no eyes visible on surface.

Peristomium with deep ventral groove, and dorsal semicircle of cirri.

Branchiae two pairs, on third and fourth somites; moderate; anterior pair considerably the larger and more richly branched; main branches arising near the base; beyond the first ramification, the branching is dichotomous (Fig. 169).

Setigerous lobes begin on fourth somite, increase slightly in size towards middle of thorax, then diminish; the last few pairs very small. Setae of form usual in this genus (Fig. 170).

Uncinigerous tori begin at fifth somite; first six pairs shorter than the rest; gradually increasing in length to the seventh where they attain the maximum length, and retain it to the 16th or 17th, at which point they gradually diminish, becoming flattened and almost indistinguishable on the abdomen. Uncini small, avicular, with five rows of teeth above the rostrum (Fig. 171 c). They are uniserial on somites 5 to 10, and on 35 to end of series; biserial, on somites 11 to 34.

Length, 160 mm.; greatest transverse diameter of thorax, 5 mm.; average of abdomen, 2 mm.; dorso-ventral diameter of thorax, 4.5 mm.

A single individual of this species was collected by Miss Robertson near Seattle.

45. ***Lanice heterobranchia*** sp. nov. Pl. 17, figs. 172-174.

Thorax of 20 somites, 17 (?) setigerous.

Prostomium of usual form; no eyes.

Branchiae three pairs, borne on somites 2-4; first pair (Fig. 172) much the largest and longest, with elongated main stem dendritically branched; ramifying branches very compact. Gills of second and third pairs short, without main stem.

Setae (Fig. 173) with striated limb on each side; tip entire, from fourth (?) somite onward. Uncini from fifth somite, uniserial, alternating ("rangée alterne," Claparède), avicular, with three teeth in front of beak (Fig. 174).

A single specimen in the Columbia University collection, too imperfect for complete description. The worm was enclosed in a mud tube. The difference in the size of the branchiae of different pairs is the most striking character.

46. *Thelepus crispus* sp. nov. Pl. 17, figs. 175-178b.

Form rather stout, not greatly tapered posteriorly; thorax passing gradually into abdomen; tapered considerably towards prostomium from tenth somite. Number of somites 88-147.

Prostomium with ample dorsal flap, transversely corrugated on dorsal surface; no eyes.

Peristomium with circlet of strongly grooved tentacles.

Branchiae (Fig. 175) three pairs, branching from the base in numerous, slender, spirally curled filaments; borne on somites 2-4.

Setae begin at third somite and extend to penultimate in young specimens; to fourteenth from pygidium in older ones; with striated limb on each side; sometimes slightly bent (Figs. 176, 177).

Uncinigerous tori begin at fourth somite; uncini absent from extreme end of body. *Uncini* (Figs. 178 *a, b*) single-ranked from fourth to seventh somites, inclusive, and gradually returning to this condition towards end of series; in flattened rings from eighth somite ("rangée parabolique," Claparède) onward. *Tori* attain their greatest length between the twelfth and twenty-fourth somites; thence diminish very gradually to end of body; those of the abdomen rounded and wart-like.

Length of large female specimen, 270 mm.; greatest transverse diameter (at sixteenth somite), 18 mm.; dorso-ventral diameter, 12 mm.

This fine Terebellid is represented in the Columbia University collection by a single large female turgid with eggs. It occurs on the California coast as far south at least as San Francisco, and is abundant at Bolinas, Marin County. Its tube is formed of coarse sand or gravel. It frequently harbors commensal individuals of *Polynoe insignis*, and northward, probably also *Harmothoe tuta* (see p. 394).

SABELLIDAE.

47. *Bispira polymorpha* sp. nov. Pl. 17, figs. 179-183. Pl. 18, figs. 184, 185.

Form nearly terete, dorsum flattened in adult specimens; in young specimens, form slender; tapered gradually at posterior end to a minute pygidium; anus terminal. Somites, 170 or more.

Thorax (Fig. 179) of nine somites, one sixteenth to one ninth of entire length (exclusive of branchiae) according to degree of contraction and probably also the age of the specimen.

Branchiae (Fig. 179) about as long as thorax, dichotomously branched twice or thrice in some specimens, in others unbranched; pinnate, radioles slender; 16-30 branchiae on each side, forming a spiral of 2-3 turns; each rachis with 2-10 black eye-spots (Fig. 184).

Tentacles flattened, lanceolate, about one fifth the length of branchiae.

Fecal groove extending forward along mid-dorsal line of abdomen to thorax; at posterior boundary of thorax passing on the left side to mid-ventral line of same, and thence to oral region.

Peristomium with raised anterior border or "collarete," deeply notched in mid-dorsal line, and produced into two pointed processes adjoining the ventral sulcus.

Thoracic setae (Figs. 180, 181) begin on second somite; of two forms, winged-capillary and mucronate-spatulate; the latter more numerous, forming a close series towards the torus.

Uncinigerous tori of thorax dorsal to setigerous tubercles; begin on third somite; separated by full width of dorsum; uncini biserial, of two sorts (Fig. 182), avicular and dilated-cuspidate; both kinds with long manubria; the points directed cephalad. Abdominal setae all of one kind (Fig. 185) arising from smaller tubercles, which are placed dorsad to the uncinigerous tori. Uncini (Fig. 183) uniserial, all avicular, with a shorter manubrium than the thoracic uncini; rostra directed anteriorly.

Tube cartilaginous, translucent, adherent to rocks, piles, etc.

Length of average specimen (exclusive of branchiae), 95 mm.; greatest transverse diameter, 6 mm. Greatest transverse diameter of largest specimen at hand, 12 mm.

Numerous specimens from the Puget Sound region, collected at Neah Bay and in the Port Townsend district by the Columbia University Expedition, and at Alki Point and Port Orchard by Miss Robertson. It occurs also on the California coast as far south as Pacific Grove.

This species is remarkable for the highly variable aspect which it presents, owing to the diverse coloration of the branchiae and the differences of shape caused by different states of contraction in which it has been killed. If killed within the tube, it is almost perfectly cylindrical and often of great length, owing to the impossibility of expansion within the rigid and tightly fitting tube. The longest specimen thus killed (posterior somites lacking) measures not less than 150 mm. in length and only 5 mm. in greatest trans-

verse diameter. Even more striking, although not always perceptible to the naked eye, is the variable character of the branchiae, which are in some specimens dichotomously branched, and in others entirely unbranched.

The coloration of the branchiae shows two distinct phases — purple or wine-color and whitish or tawny. Either color may be present to the exclusion of the other, or the two may be in alternate, transverse bands. The eye-spots may be few or many, but I have found no specimen without them. Although a lens is absent, the eye-spot produces a wart-like elevation of the cuticula which covers it (Fig. 184). The eye-spots are of various sizes, the largest being over twice the diameter of the smallest. They are scattered at irregular intervals along the rachis, but are more numerous towards the base than towards the tip. None are found near the tip and very rarely any on the branches.

The tube is adhesive, and is usually affixed by its lower extremity or by its side to a stone or pile. At Pacific Grove the species attains a large size and is abundant on rocky bottoms from low-water mark to a depth of several fathoms.

Megachone gen. nov.

Form terete; no ventral shields; collarette flaring, interrupted only at ventral notch; branchiae connected by a web; no spatulate thoracic setae; thoracic uncini with long manubrium, of one kind only; abdominal uncini short avicular plates; no ventral fissure at posterior end.

48. **Megachone aurantiaca** sp. nov. Pl. 18, figs. 186–192.

Form subcylindrical, spiral in contraction, thickest in posterior portion; anterior end truncated; collarette broad (Figs. 186, 187); body narrowed in region of thorax and enlarged in abdomen; posterior extremity abruptly tapered to a minute tip, which is curved dorsad; anus terminal. Somites 75 in number.

Branchiae 20 on each side, unbranched (Figs. 187, 188), closely appressed, tips pointing ventrad; radioles invisible until branchiae are raised.

Thorax (Fig. 186) of eight somites; peristomium, with collarette, one and one half times the length of the other thoracic somites; bears a small tuft of setae, but no uncini; a slight indication of two rings; the biannulate condition more strongly marked in the other thoracic and abdominal somites.

Fecal groove extending forward along mid-dorsal line to ninth

somite, there passing on the left side to mid-ventral line, and thence to oral notch. Setigerous tubercles small.

Capillary setae (Fig. 189) of thorax single or double-bordered; uncinigerous tori (Fig. 186) short, small; uncini avicular, with very long manubria, uniserial, or incompletely biserial (Fig. 190); setae of the abdomen very similar to those of thorax; uncini of abdomen (Figs. 191, 192) with much elongated rostra.

Length, 87 mm.; transverse diameter of collar, 5 mm.; greatest transverse diameter of abdomen, 4.5 mm.

This species is represented by a single specimen, collected by Miss Robertson at Port Orchard, on July 4, 1898. The specimen was preserved in formalin and the color when first received (no doubt nearly that of the living worm) was a bright orange. The worm is undoubtedly a tube-dweller, but there are no data concerning a tube or the precise habitat.

As suggested to me by Professor Verrill, the branchiae of this specimen are in all probability in process of regeneration.

ERIOGRAPHIDAE.

49. *Myxicola pacifica* sp. nov. Pl. 19, figs. 193-198.

Body fusiform, terete; tapered slightly towards anterior, much more, and gradually, towards posterior extremity; somites 67-97 in number, short, biannulate; no collarette; two fleshy processes (tentacles?) on first somite, adjacent to mouth; thorax hardly distinguishable from abdomen and composed of nine somites.

Branchiae (Fig. 193) 14 on each side, connected by a web (*w.*) as far as radioles extend, *i. e.*, within 3 mm. of tip; radioles slender, biserial; tips of branchiae spirally coiled in retraction.

Thoracic setae of two forms: (1) double-bordered capillary (Fig. 194), very slender, often twisted; and (2) blunt, spinous setae (Fig. 195) with conical tips, much fewer in number; both kinds occur together in tufted fascicles. Uncini of thorax with long manubria (Fig. 197), strong rostra, and minute teeth; uniserial. Abdominal setae (Fig. 195) slender, minute, very broadly double-bordered; abdominal uncini (Fig. 198) very minute, avicular, 2-3 teeth above rostrum; arranged in tori which nearly encircle the body, being interrupted only by the setigerous papillae and a median stripe on dorsum; uniserial.

Length of large specimen (not including branchiae), 60 mm.; greatest transverse diameter of same, 9 mm.; length of retracted branchiae, 21 mm.

This species is represented by two female specimens, one collected by Miss Robertson at Port Orchard in June, 1899, the other by Professor Ritter at Pleasant Beach in May of the same year. Although exhibiting great difference as to size — one being more than twice the length of the other — they both contain nearly ripe ova, indicating sexual maturity.

The transparent mucous envelope so characteristic of this genus was preserved with both specimens.

SERPULIDAE.

50. *Serpula columbiana* sp. nov. Pl. 19, figs. 199–204.

Form subterete; somewhat flattened dorso-ventrally; gradually tapered towards posterior extremity; fecal groove distinct, dorsal as far as thorax, there branching and passing to the ventral side under the thoracic membrane.

Thorax with seven setigerous somites, well-developed collarette, and thoracic membrane, the latter reaching to the tips of the setae. Abdominal somites, 250 or more.

Branchial filaments 54 on each side, arranged in two spirals ascending from the ventral edges, each making a complete turn, then extending mesad and meeting each other just over the mouth. Branchiae whitish, beautifully banded with scarlet or crimson; distribution of color variable but usually a broad red band at or near base, followed by two narrow bands, and branchiae broadly tipped with the same. Operculum (Fig. 199) on right side, its mate on the left very short and rudimentary; funnel-shaped, with about 100 ribs which form a notched border; deep, funnel-shaped cavity; pedicle geniculate just below the operculum.

Bayonet-setae of first setigerous somite as in Fig. 200; the other thoracic setae broadly striate-bordered (Fig. 201). Uncini of thorax and abdomen similar in shape, 6–8 toothed; the tip of largest tooth often turned outward (Figs. 202, 203). Chisel-shaped setae of abdomen as shown in Fig. 204.

Tube white, calcareous, more or less coiled; anterior portion of old tubes often free from the substratum to which tube is attached.

Length of large specimen, 55 mm.; greatest transverse diameter of thorax, 7 mm.; of abdomen, 6 mm.

This beautiful Serpulid is abundant in Puget Sound. Harrington and Griffin ('97, p. 103) mention a handsome *Serpula*, probably this species, which forms "hard white tubes" on the rocky bottom of Hood's Canal; and also as "whitening the rocks with its calcareous tubes," along the beaches near Port Townsend. It was collected at Alki Point by Miss Robertson. It occurs also on the California coast at Bolinas (Duxbury Reef), and at Lime Point and Point Cavallo, on the northern shore of the Golden Gate. Its favorite habitat is the under side of a stone where the water flows freely. If not in a tide-pool, it is near extreme low-water mark.

The uncini show considerable variation on the same individual, and even on the same torus. The number of teeth ranges from six to eight; the upper border is high-arched or nearly straight. The tip of the large tooth may or may not be recurved.

The coloration of the branchiae is also variable, both as to tint and distribution. It is either scarlet or damask-red, and it may involve nearly the whole of the branchiae and operculum, or may be more restricted, so that the white predominates. If formalin specimens are not exposed to direct sunlight the color is retained for years in almost its original brightness.

This may possibly be identical with *Serpula jukesii* Baird, described by Grube ('77) from North Japan. His description is too brief, however, to put the question of identity beyond doubt.

51. *Serpula zygophora* sp. nov. Pl. 19, figs. 205-208.

Form nearly cylindrical; abdomen strongly grooved on dorsal aspect, the somites marked on each side by transverse ridges; seven thoracic setigerous somites.

Branchiae spiral, thirty filaments on each side; carmine-red at base, and broadly barred with the same; operculum (Fig. 205) on right side, funnel-shaped, moderately cupped, 26-ribbed, the ribs extending to the center of the concavity; base yoke-shaped; pedicel long and curved, geniculate just below the operculum; corresponding filament of left side club-shaped. Operculum and pedicel variegated with red.

First *setigerous somite* with bayonet-setae (Fig. 206). Thoracic uncini six-toothed (Fig. 207); abdominal uncini (Fig. 208) five- or six-toothed. Chisel-shaped abdominal setae almost identical with those of *Serpula columbiana*. Transverse diameter of thorax, 3.5 mm.; of abdomen, 3 mm. Tube lacking.

This species is represented by a single imperfect specimen (lacking posterior portions), collected by Miss Robertson at Alki Point. As it has never been collected, so far as known, on the California coast, it may be inferred that its distribution is northward.

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PLATE 1.¹

Fig. 1. Anterior extremity, dorsal aspect, of *Polynoe fragilis*. The elytra have fallen off. $\times 8.5$.

Figs. 2-7. *Harmothoe iphionelloides*.

Fig. 2. Anterior extremity, dorsal aspect; proboscis exerted; anterior elytra removed. $\times 8.5$.

Fig. 3. Fifth elytron, right side. $\times 8.5$.

Fig. 4. Third foot from right side, dorsal aspect. The setae above the dorsal cirrus all belong to the dorsal fascicle. $\times 23$.

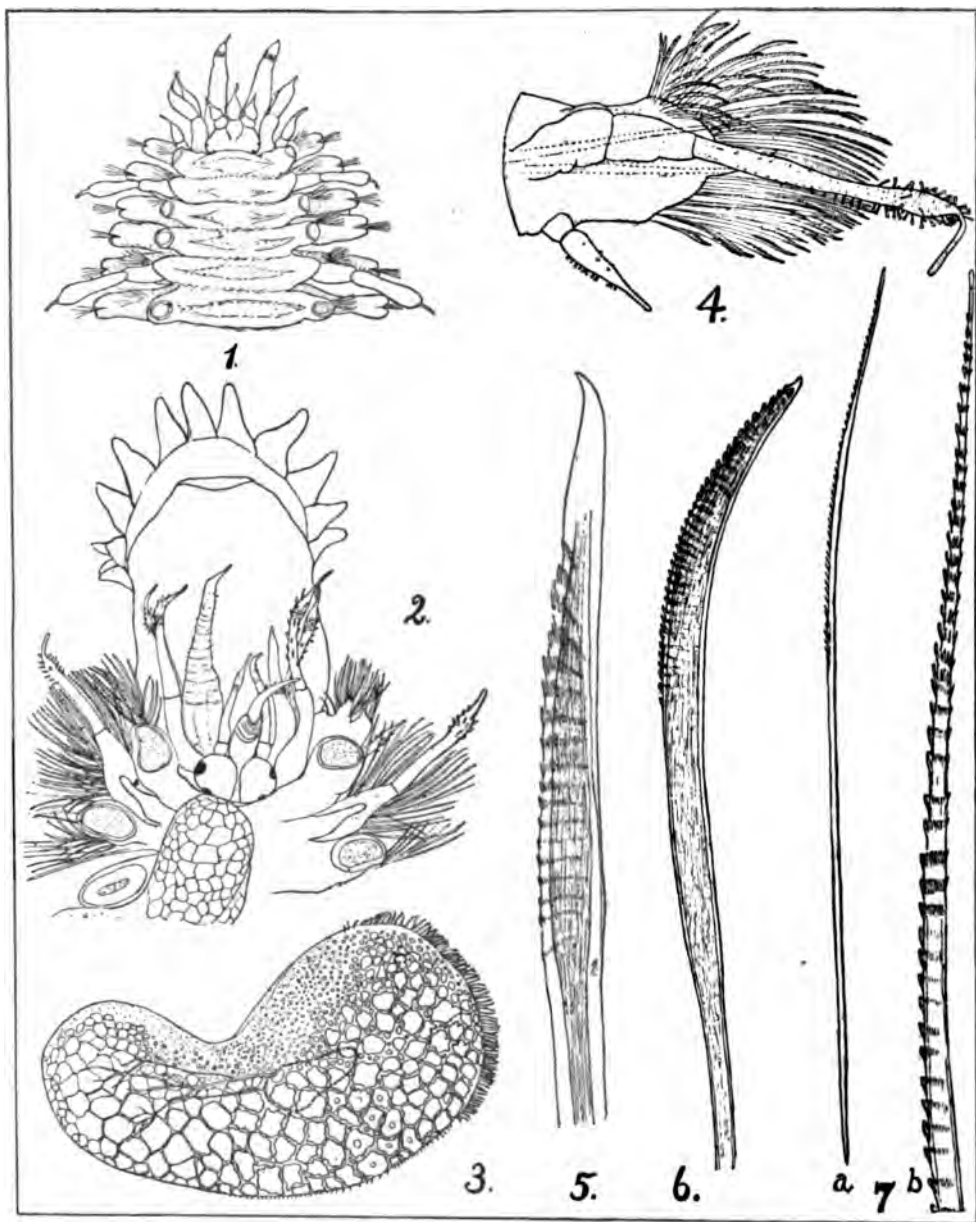
Fig. 5. Ventral seta-tip, profile. $\times 200$.

Fig. 6. Stout, curved, dorsal seta. $\times 200$.

Fig. 7. a. Slender dorsal seta. $\times 53$.

b. Tip of same, more magnified. $\times 200$.

¹ With very few exceptions (in each instance, stated), the figures are from camera drawings. In all the plates the drawings have been reduced one-half, and the magnification, as given with the explanation of each figure, has been corrected accordingly.



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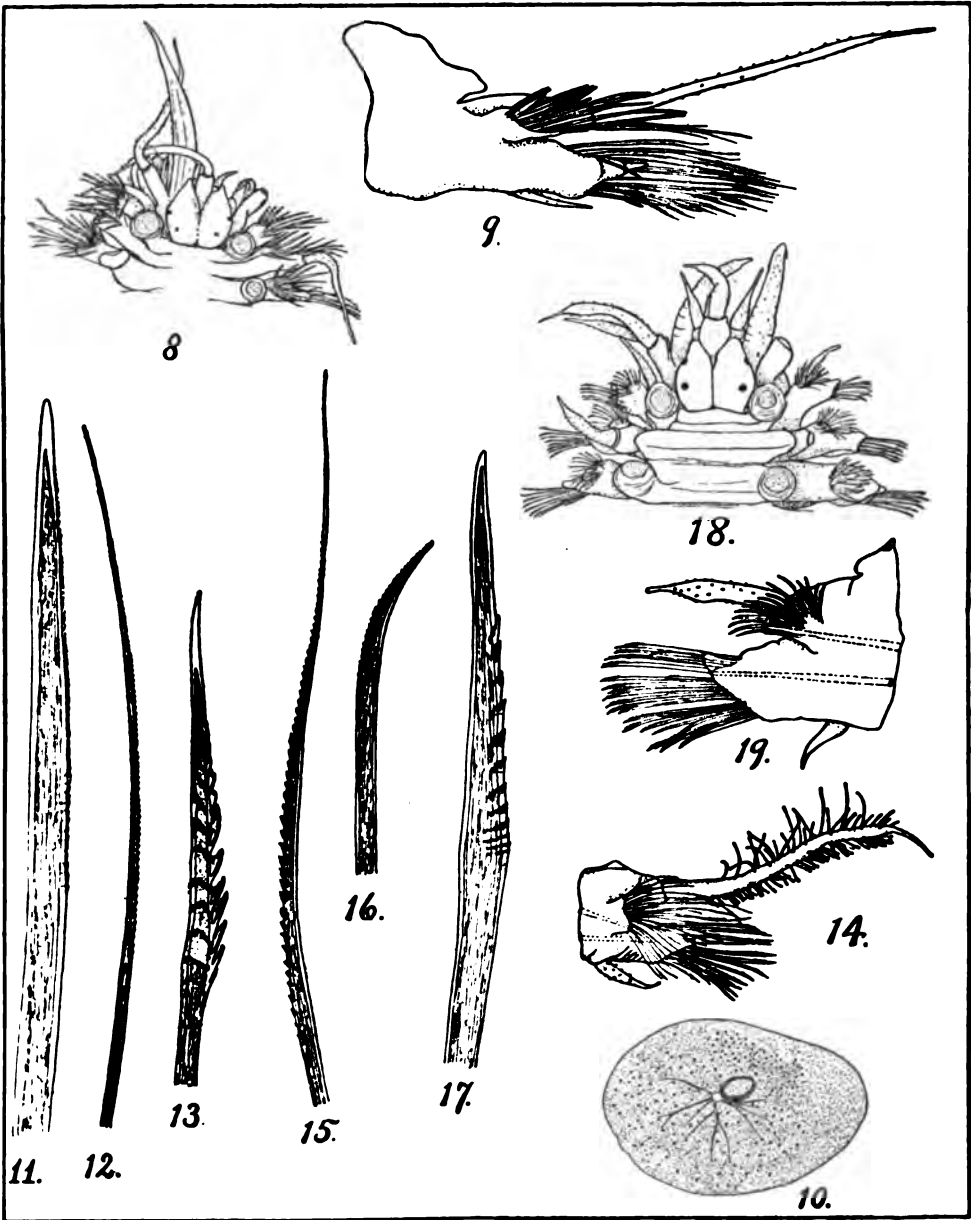
PLATE 2.

Figs. 8-13. *Harmothoe complanata*.

- Fig. 8. Anterior extremity, dorsal aspect. $\times 13$.
- Fig. 9. Twenty-first foot, anterior aspect. $\times 23$.
- Fig. 10. Elytron from left side; the nerves radiating from the elytophore are distinctly seen. $\times 13$.
- Fig. 11. Tip of stout dorsal seta. $\times 200$.
- Fig. 12. Top of slender dorsal seta. $\times 100$.
- Fig. 13. Tip of ventral seta. $\times 200$.

Figs. 14-17. *Harmothoe pacifica*.

- Fig. 14. Anterior aspect of second foot. $\times 13$.
- Fig. 15. Tip of slender, slightly curved dorsal seta. $\times 100$.
- Fig. 16. Tip of strongly-curved dorsal seta. $\times 100$.
- Fig. 17. Tip of ventral seta. $\times 100$.
- Fig. 18. *Harmothoe tuta*; anterior extremity, after removal of elytra. $\times 8.5$.
- Fig. 19. Seventeenth parapod of the same. Anterior aspect. $\times 17$.



H.P.J. del.

PLATE 3.

Figs. 20-22. *Harmothoe tuta*.

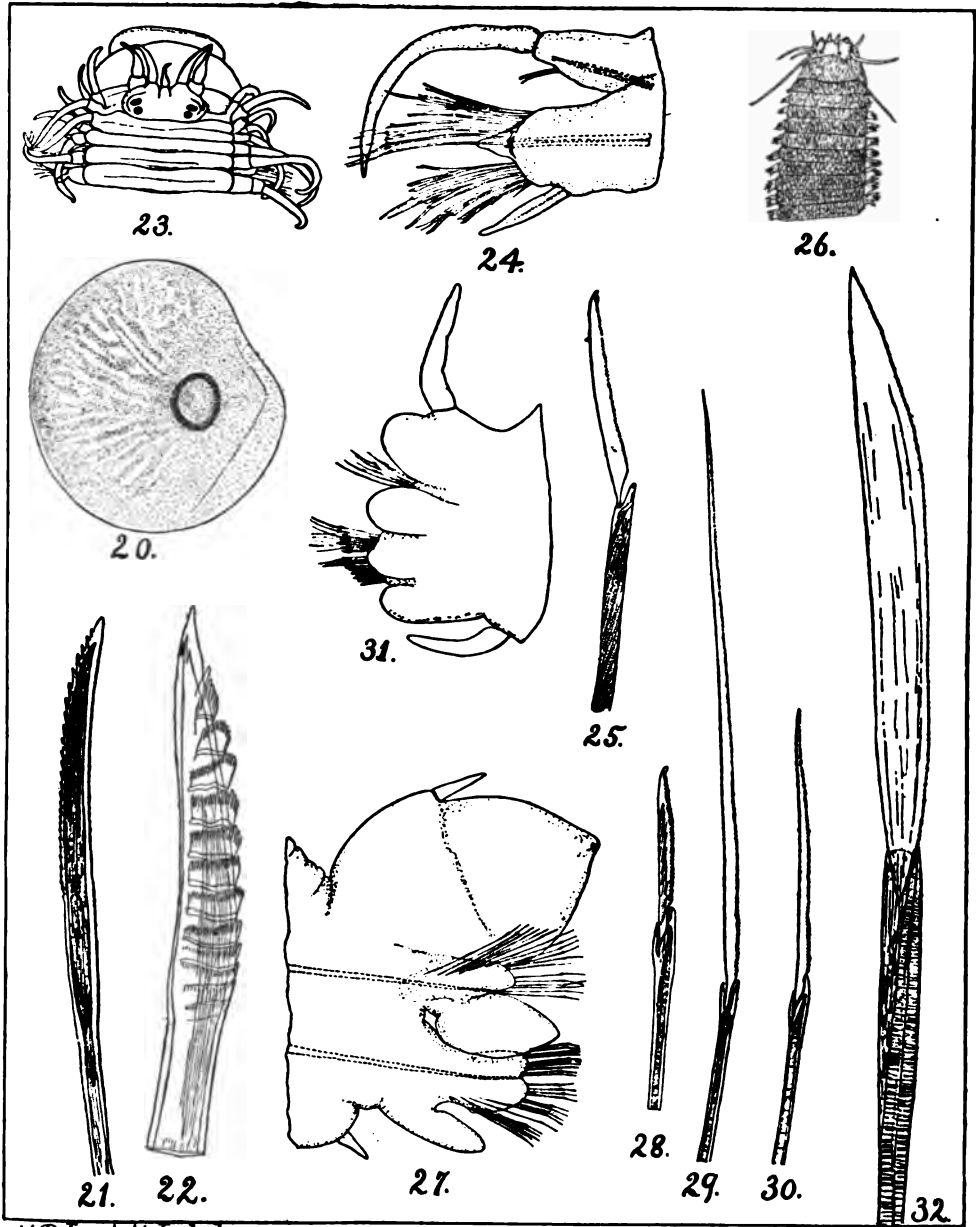
- Fig. 20. Elytron from left side. $\times 6.5$.
Fig. 21. Dorsal seta from eighteenth foot. $\times 200$.
Fig. 22. Ventral seta-tip from eighteenth foot. $\times 200$.

Figs. 23-25. *Podarke pugettensis*.

- Fig. 23. Anterior extremity, proboscis exerted. $\times 16$.
Fig. 24. Parapod from middle of the body. $\times 32.5$.
Fig. 25. Tip of a ventral (compound) seta. $\times 200$.

Figs. 26-30. *Nereis virens*.

- Fig. 26. Anterior extremity, dorsal aspect, of large specimen. $\times 0.5$.
Fig. 27. Foot from middle of body, anterior aspect. $\times 8.5$.
Figs. 28-30. Tips of setae from ventral fascicle, showing graduation in length of appendage. $\times 150$.
Fig. 31. Tenth foot of *Nereis vexillosa*, posterior aspect. $\times 23.5$.
Fig. 32. Natatory seta, female *Heteronereis* of *N. vexillosa*. $\times 200$.



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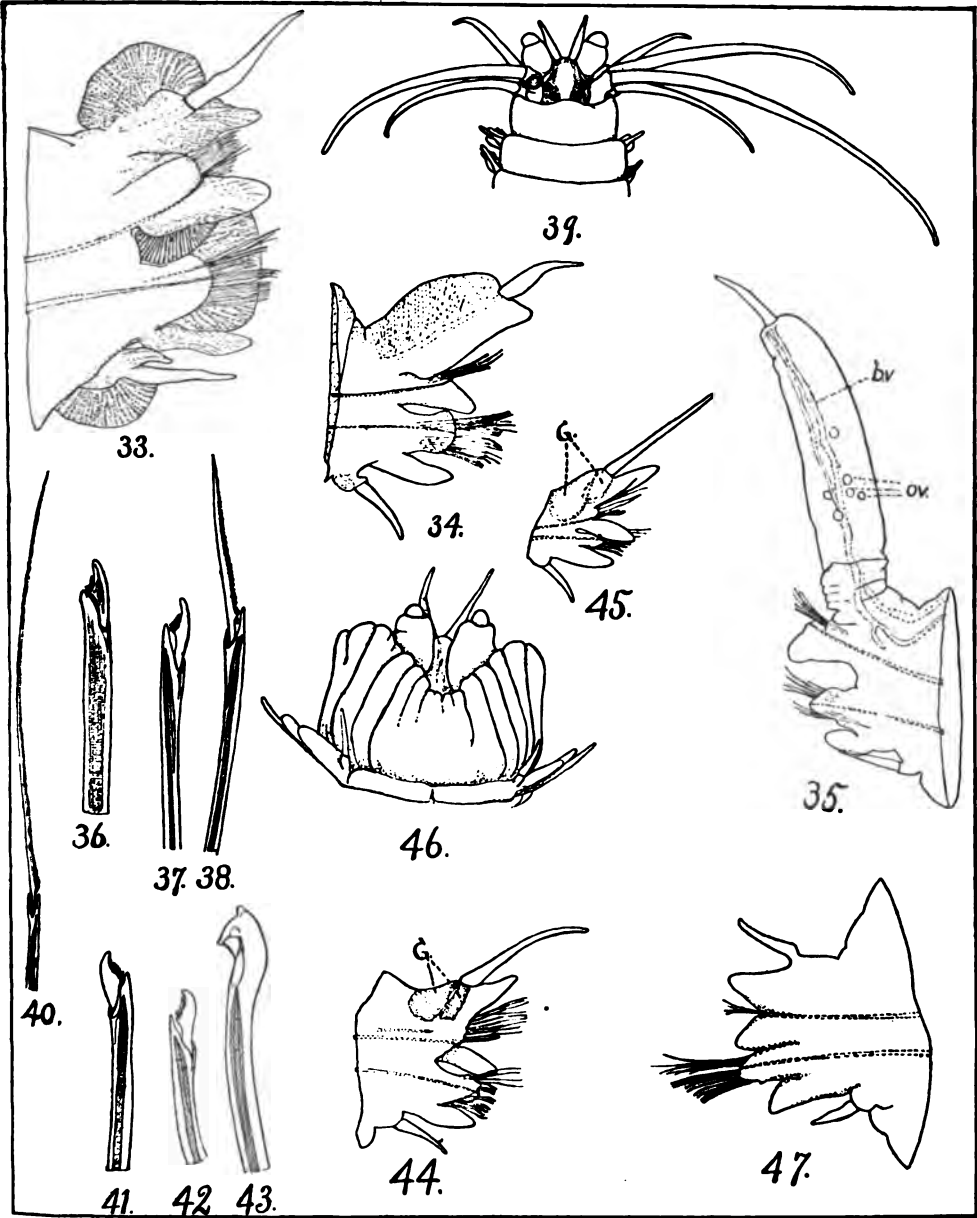
PLATE 4.

Figs. 33-38. *Nereis vexillosa*.

- Fig. 33. Anterior aspect of heteronereized foot. $\times 8.5$.
Fig. 34. Foot from posterior portion of body of young female. $\times 8.5$.
Fig. 35. Foot from posterior region of large adult female, with much elongated dorsal lobe. *b. v.* Blood-vessel. *ov.* Ova lying within coelomic space. $\times 8.5$.
Fig. 36. Stout sickle-shaped seta from dorsal ramus. $\times 150$.
Figs. 37, 38. Sickle-shaped and "fish-bone" setae from ventral ramus. $\times 150$.

Figs. 39-45. *Nereis agassizi*.

- Fig. 39. Anterior extremity. $\times 8.5$.
Fig. 40. "Fish-bone" seta from dorsal ramus. $\times 200$.
Figs. 41, 42. Sickle-shaped setae from ventral ramus. $\times 200$.
Fig. 43. Hooked seta from dorsal ramus. $\times 200$.
Fig. 44. Foot from middle of series. The glands (*g.*) at base of upper lobe are shown. $\times 23$.
Fig. 45. Foot from posterior portion of body. $\times 23$.
Fig. 46. Anterior, ventral aspect of a young *Nereis cyclurus*. The prostomium is partially withdrawn into the large, collar-like peristomium. $\times 8.5$.
Fig. 47. *Nereis procera*; foot from anterior portion of body. $\times 23.5$.



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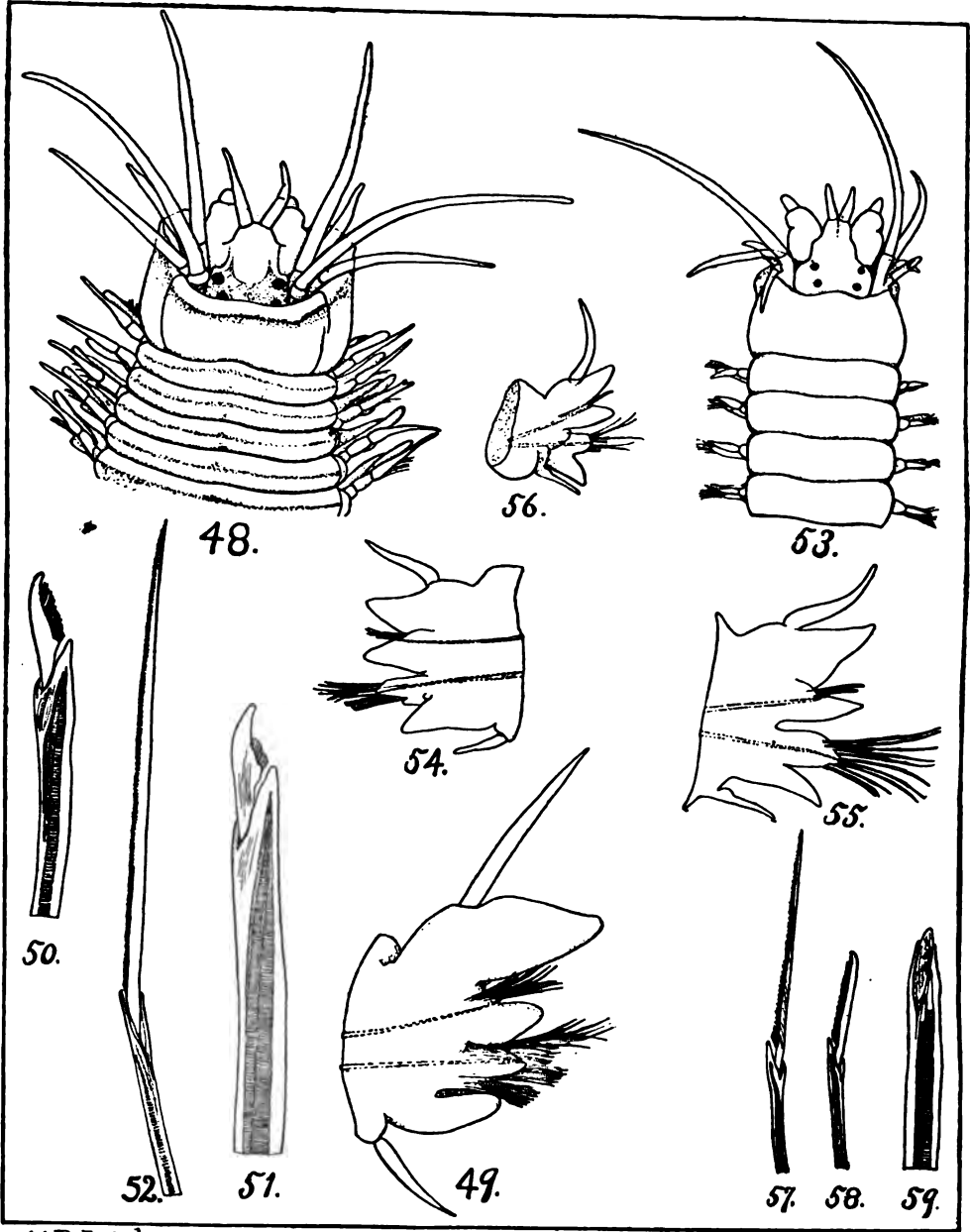
PLATE 5.

Figs. 48-52. *Nereis cyathurus*.

- Fig. 48. Anterior extremity, dorsal aspect, showing large, collariform peristomium, within which the prostomium is partially withdrawn. Young specimen. $\times 8.5$.
Fig. 49. Tenth foot, anterior aspect. $\times 13$.
Fig. 50. Falcate seta from lower fascicle, ventral ramus, of foot from anterior region of body. $\times 200$.
Fig. 51. Falcate seta from upper fascicle of ventral ramus. $\times 200$.
Fig. 52. "Fish-bone" seta, upper fascicle, ventral ramus. $\times 200$.

Figs. 53-59. *Nereis procera*.

- Fig. 53. Anterior extremity, dorsal aspect. $\times 8.5$.
Fig. 54. Forty-first foot, showing stout, dorsal seta and three slender ones. $\times 23$.
Fig. 55. Foot further back; slender dorsal setae no longer present. $\times 23$.
Fig. 56. Foot from posterior region, near pygidium. $\times 23$.
Figs. 57, 58. "Fish-bone" and falcate setae from ventral ramus. $\times 200$.
Fig. 59. Stout dorsal seta. $\times 200$.



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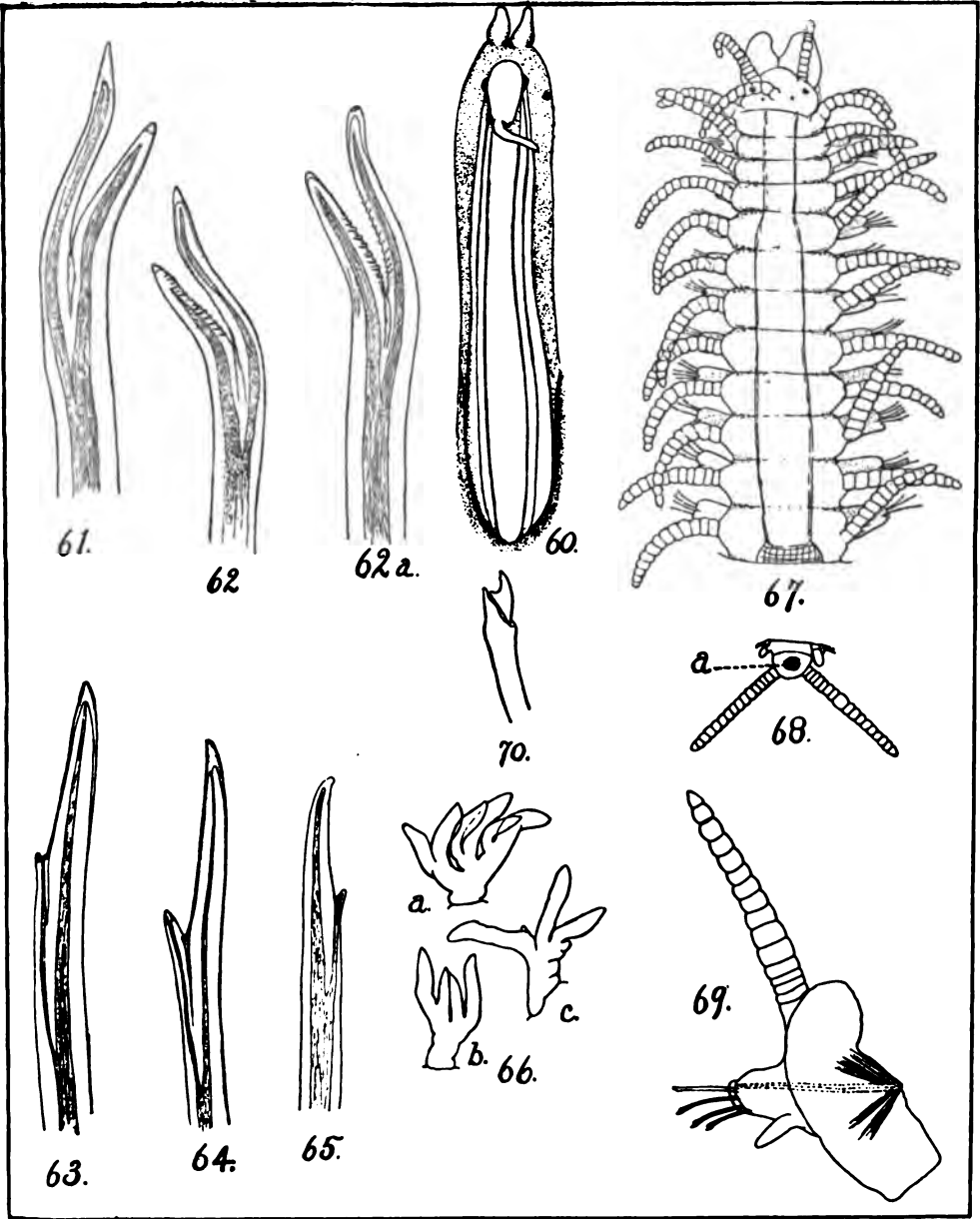
PLATE 6.

Figs. 60-66. *Euprosyne heterobranchia*.

- Fig. 60. The prostomium, dorsal aspect, showing the antennae, the tentacle, the dorsal eyes, and the caruncle. $\times 40$.
Fig. 61. Tip of one of the unserrated, cleft, dorsal setae. $\times 200$.
Fig. 62. Tip of serrated, cleft, dorsal seta. The serrations are almost restricted to the lower fork. $\times 200$.
 a. Tip of another seta of same kind, fully serrated. $\times 200$.
Figs. 63, 64. Bifid, dorsal setae of two forms. $\times 200$.
Fig. 65. Ventral seta of the usual form. $\times 200$.
Fig. 66 *a, b, c.* Various forms of branchiae. $\times 32$.

Figs. 67-70. *Pionosyllis elongata*.

- Fig. 67. Anterior portion of immature specimen (146 somites). $\times 32$.
Fig. 68. Posterior extremity, showing pygidium, anus (*a.*), and anal cirri. $\times 32$.
Fig. 69. Foot from middle of body. $\times 52$.
Fig. 70. Seta tip. Minute serrations sometimes present on concave side of falcate appendage. $\times 275$.



H.P.J. del.

PLATE 7.

Fig. 71. *Pionosyllis elongata*; outline of anterior portion seen on the ventral side, showing alimentary canal *in situ*. The dorsal cirri and the setae are omitted. *pa.* Papillae. *t.* Tooth. *oes.* Oesophagus. *prov.* Proventriculus, or "gizzard." *c.* Coeca. $\times 23.5$.

Figs. 72-76. *Trypanosyllis gemmipara*.

Fig. 72. Anterior extremity, dorsal aspect. *p.* Palpus. $\times 13$.

Fig. 73. Proboscis dissected out, showing chitinous teeth and surrounding fleshy papillae (*pa.*). $\times 23.5$.

Fig. 74. Foot from anterior region of body. The monilliform character of the dorsal cirrus is too strongly indicated. *v. c.* Ventral cirrus. $\times 22.5$.

Fig. 75. Seta-tip, profile. In glycerine. $\times 237$.

Fig. 76. Caudal buds, seen from ventral aspect. The center of proliferation is on the right, where a cluster of young buds is seen. $\times 23$.

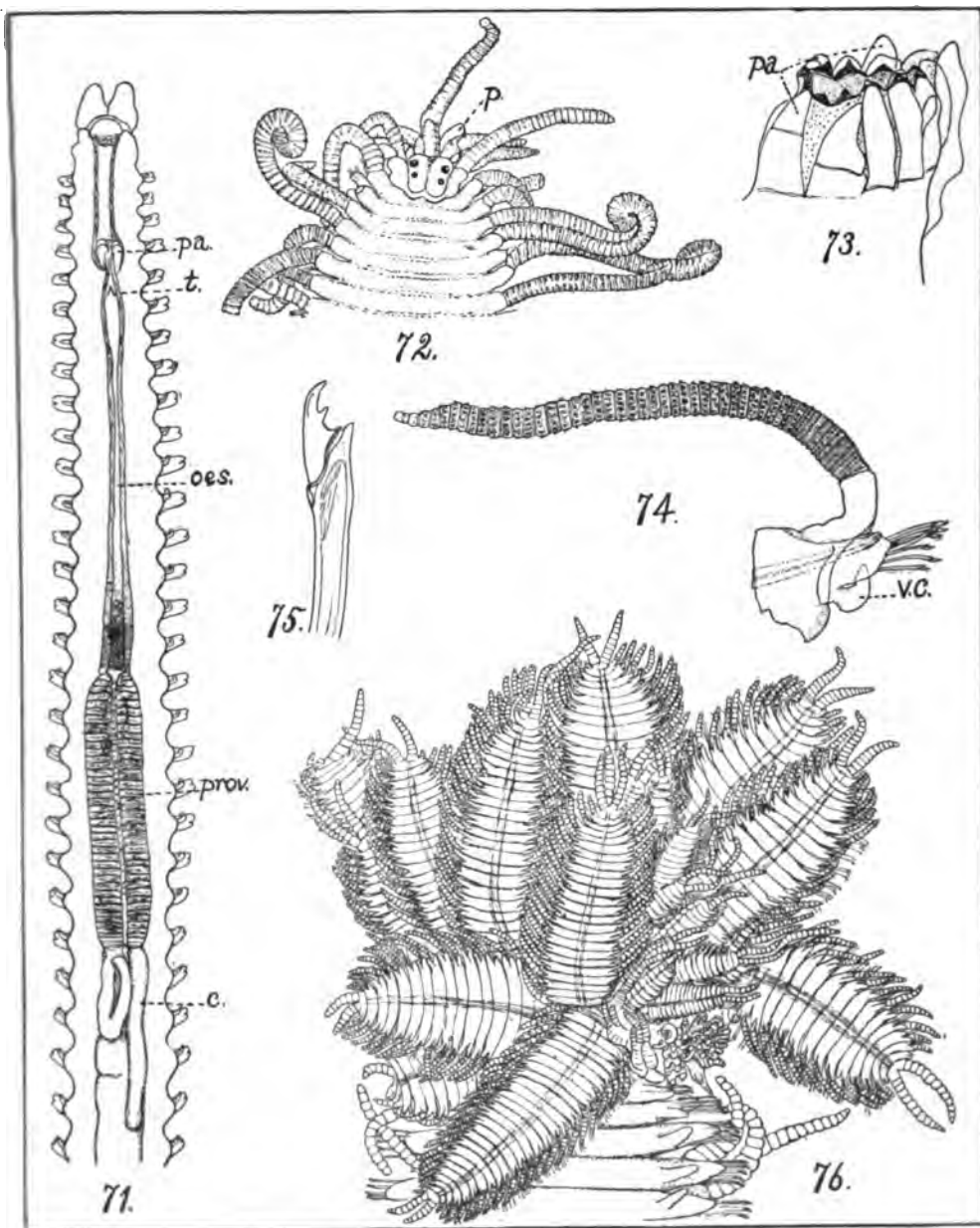
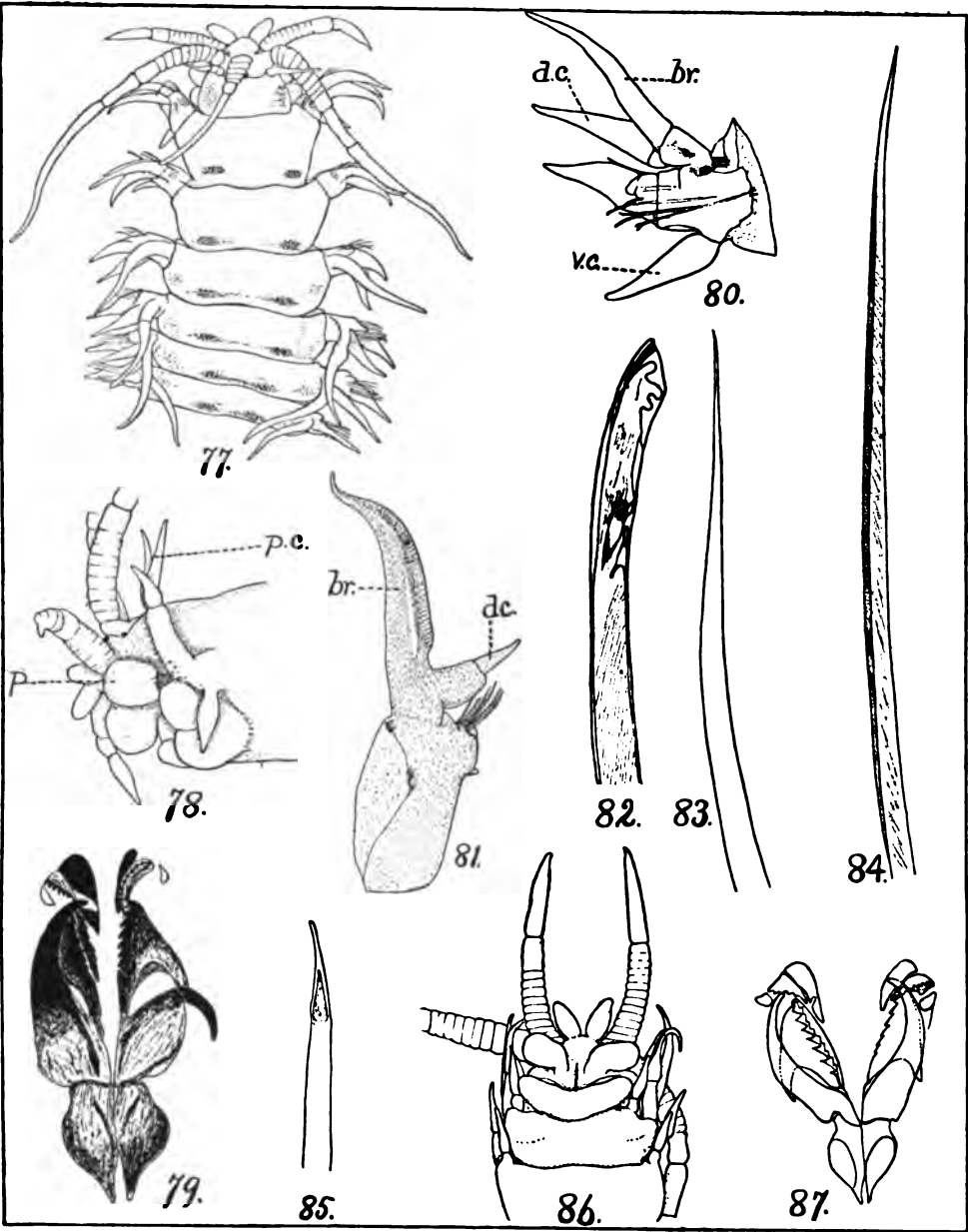


PLATE 8.

Figs. 77-85. *Northia elegans*.

- Fig. 77. Anterior extremity, dorsal aspect. $\times 6$.
Fig. 78. Anterior extremity, specimen lying obliquely on right side. The minute eyes are visible at base of left articulated antenna. *p. c.* Peristomial cirri. *p.* Palpus. $\times 8.5$.
Fig. 79. Maxillae, somewhat spread apart, and the right edentate maxilla folded back, to show underlying toothed jaw. $\times 16$.
Fig. 80. Anterior aspect of second foot. *br. Gill. d. c.* Dorsal cirrus. *v. c.* Ventral cirrus. $\times 13$.
Fig. 81. Twenty-eighth foot, profile view. (Lettering as in Fig. 80.) $\times 13$.
Figs. 82, 83. Uncinus or "hooded crotchet," and capillary subulate seta, both from ventral fascicle of third parapod. $\times 200$.
Fig. 84. Capillary seta with striated border, ventral fascicle of thirty-first foot. $\times 200$.
Fig. 85. Concave seta (buried in foot) from dorsal fascicle of thirty-first foot. $\times 200$.
Fig. 86. Anterior extremity, ventral aspect, of *Northia iridescens*. $\times 8.5$.
Fig. 87. Maxillae of the same, spread widely apart, and seen from dorsal aspect. $\times 16$.



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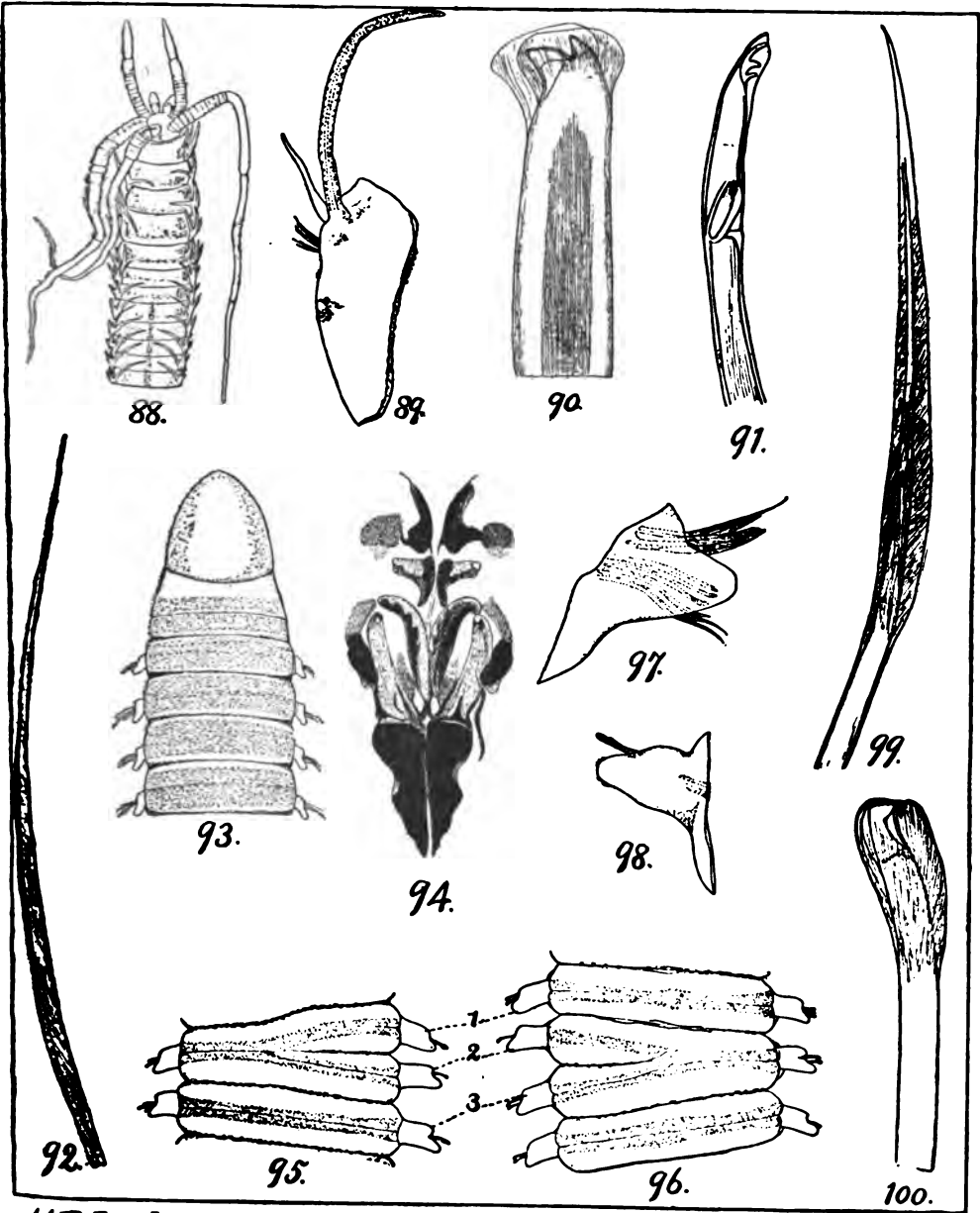
PLATE 9.

Figs. 88-92. *Northia iridescens*.

- Fig. 88. Anterior extremity, dorsal aspect. Free-hand drawing. $\times 3$.
Fig. 89. Foot from middle of series, showing the filiform gill and subulate dorsal cirrus. $\times 23.5$.
Fig. 90. Wing-tipped uncinus, from a middle parapod. $\times 200$.
Fig. 91. Hooded crotchet from ventral fascicle of third foot. $\times 190$.
Fig. 92. Capillary seta with striated border. $\times 200$.

Figs. 93-100. *Lumbriconereis zonata*.

- Fig. 93. Anterior extremity, dorsal aspect. $\times 8.5$.
Fig. 94. Maxillae, somewhat spread apart, and seen from the dorsal side. $\times 23.5$.
Figs. 95, 96. A "spiral" somite from posterior region of body, seen from the dorsal (Fig. 95) and from the ventral aspect (Fig. 96); 1, 2, 3, the somites involved. $\times 8.5$.
Fig. 97. Fifteenth foot, posterior aspect. $\times 40$.
Fig. 98. Foot from middle of series, posterior aspect. Uncini only are present. $\times 23.5$.
Fig. 99. Double-bordered seta from an anterior foot. $\times 237$.
Fig. 100. "Hooded crotchet" from a posterior foot. $\times 237$.



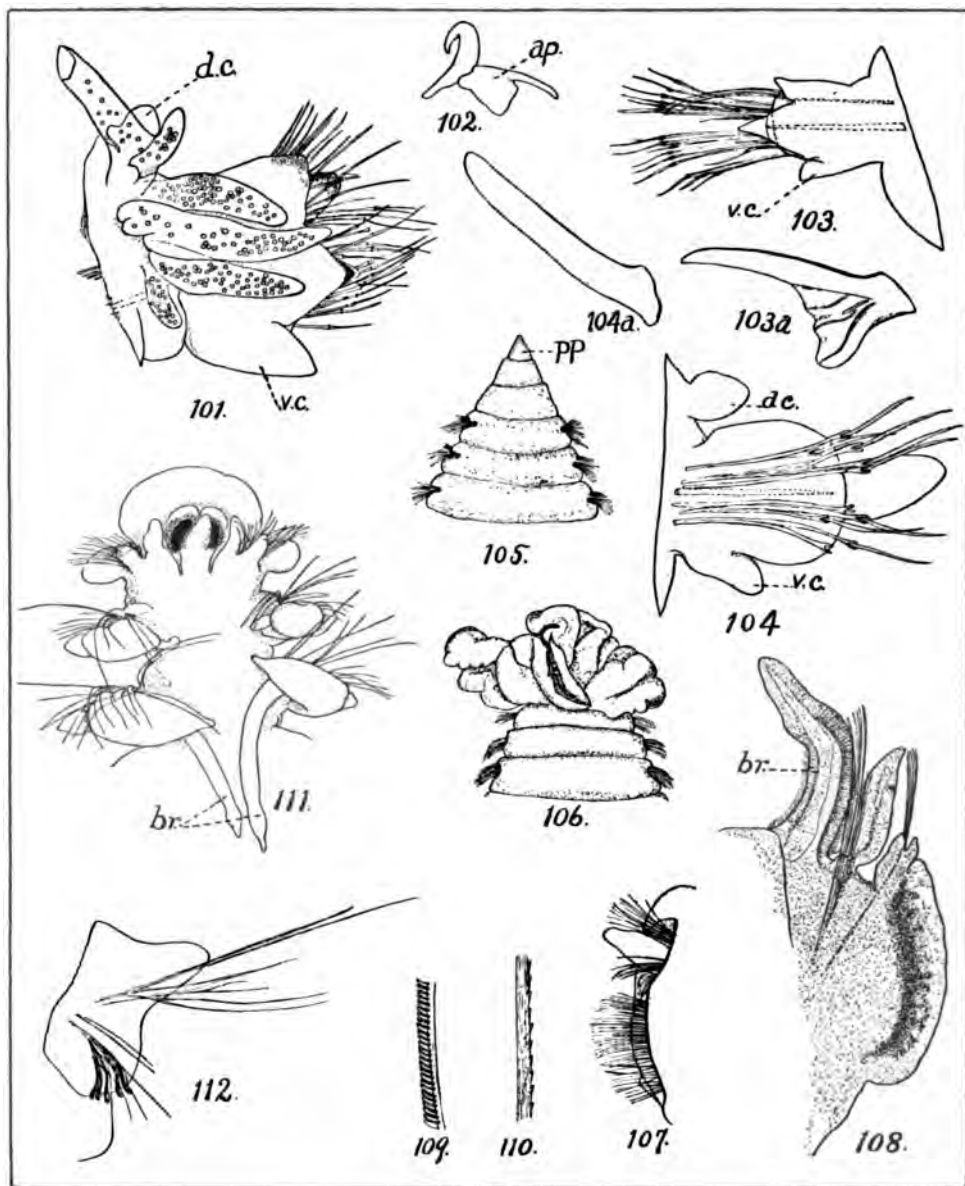
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PLATE 10.

- Fig. 101. Posterior aspect of foot of *Glycera rugosa*, from middle of body showing 6-lobed gill, and dorsal cirrus (*d. c.*) seen by transparency through uppermost lobe of gill (the tip of which has been cut off). The minute ova have entered the gills. *v. c.* Ventral cirrus. $\times 23.5$.
- Fig. 102. Jaw and jaw-appendage (*ap.*) of the same. $\times 13$.
- Fig. 103. Posterior aspect of foot of *Glycera nana*. Dorsal cirrus is not shown. *v. c.* Ventral cirrus. $\times 23$.
- Fig. 103a. Jaw-appendage of the same. $\times 40$.
- Fig. 104. Posterior aspect of a foot from middle of series of *Hemipodia borealis*. Setae are all compound, and several are almost entirely withdrawn within the foot. The single acicula is indicated by dotted lines. *d. c.* Dorsal cirrus. *v. c.* Ventral cirrus. $\times 75$.
- Fig. 104a. Jaw-appendage of the same. The attached end is somewhat expanded. $\times 75$.

Figs. 105–110. *Scoloplos elongata*.

- Fig. 105. Anterior extremity, dorsal aspect. *pp.* Palpode. $\times 13$.
- Fig. 106. Anterior extremity, ventral aspect, with proboscis everted, showing foliaceous expansions. $\times 13$.
- Fig. 107. Profile of seventeenth foot, anterior aspect. $\times 23.5$.
- Fig. 108. Vertical section of foot from middle of length, showing the dorsally-directed parts. *br.* Gill. $\times 52.5$.
- Fig. 109. Portion of one of the deeply-serrated, anterior setae. $\times 340$.
- Fig. 110. Portion of a ventral seta. $\times 340$.
- Fig. 111. Anterior extremity of *Aricideopsis megalops*. $\times 39$.
- Fig. 112. The same. Foot from posterior portion. $\times 39$.



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PLATE 11.

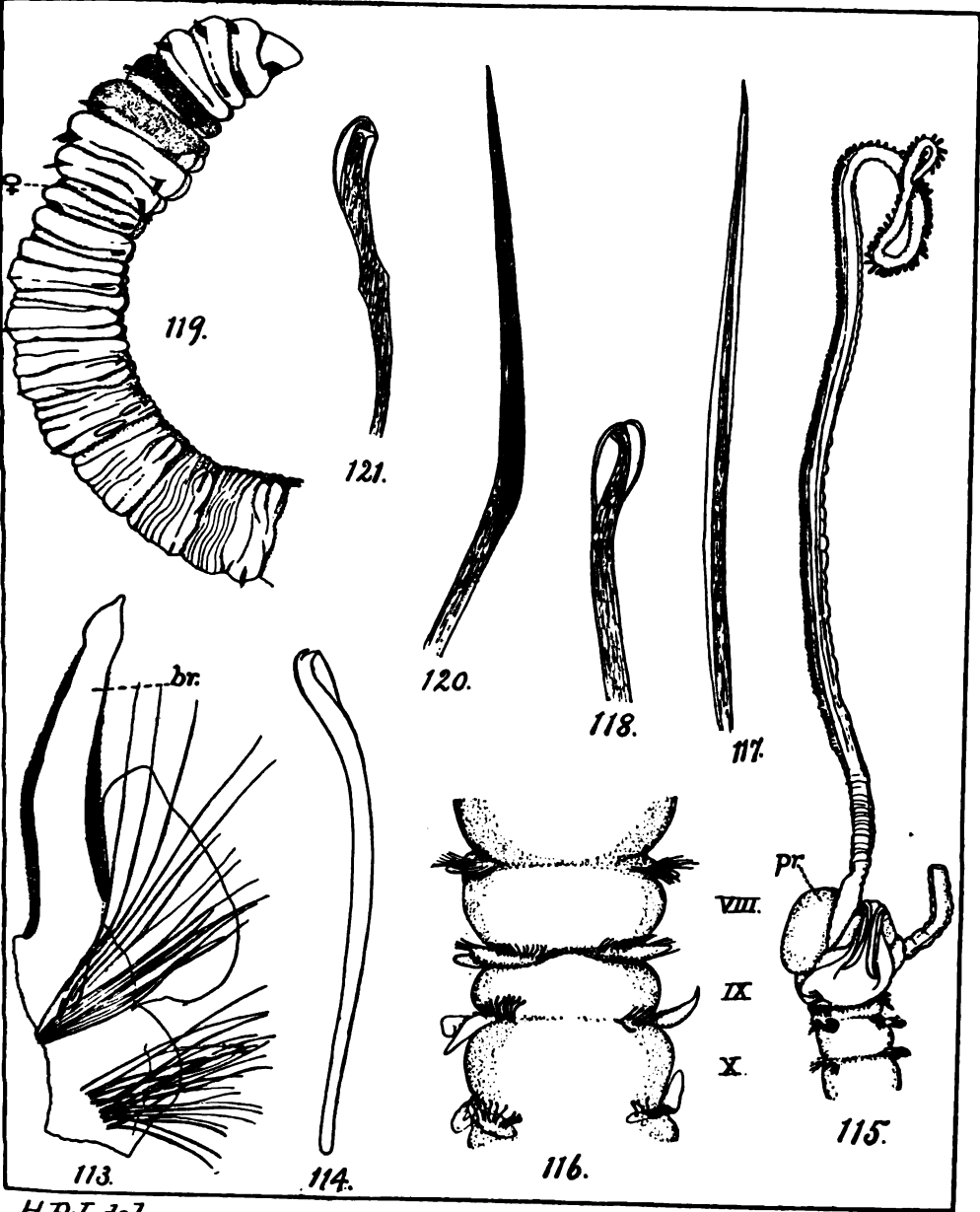
- Fig. 113. Tenth foot of *Aricideopsis megalops*, anterior aspect. The dense ciliation of the gill (*br.*) is clearly shown. $\times 39$.
Fig. 114. Hooded uncinus of the same. $\times 321$.

Figs. 115–118. *Magelona longicornis*.

- Fig. 115. Anterior end, showing one of the enormously elongated peristomial cirri, beset with papillae along the external side. Proboscis (*pr.*) does not appear to be fully everted. $\times 8.5$.
Fig. 116. Eighth, ninth and tenth somites, dorsal aspect. In this region occurs the replacement of dorsal capillary setae by dorsal uncini. $\times 21$.
Fig. 117. Capillary seta, with double border. $\times 321$.
Fig. 118. Hooded uncinus. $\times 321$.

Figs. 119–121. *Capitella dizonata*.

- Fig. 119. Anterior portion, including thorax and first seven somites of abdomen, of immature female. ♀. Genital opening. $\times 9$.
Fig. 120. Dorsal seta from fourth somite. $\times 321$.
Fig. 121. Uncinus from ventral fascicle of fourteenth somite. $\times 321$.



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PLATE 12.

- Fig. 122. Anterior extremity, lateral aspect, of *Trophonia papillata*, showing palpi (p.) and tentacles. $\times 9$.
Fig. 123. Uncinus from ventral fascicle, fifth somite, of the same. $\times 66$.

Figs. 124–127. *Flabelligera infundibularis*.

- Fig. 124. Entire worm, encased in its gelatinous envelope, which has been laid open on one side to show the worm, surrounded by clear jelly, within. The curved attitude is probably not the usual or normal one. Free-hand drawing. About natural size.
Fig. 125. Anterior extremity, showing "basket" of capillary setae, the stout lobulated palpi (p.) and slender tentacles. $\times 9$.
Fig. 126. Foot from middle of body, showing ventral hook and dorsal setae. $\times 15$.
Fig. 127. Dorsal ramus of foot, showing basal portions of setae and pedunculated sensory papillae. $\times 39$.

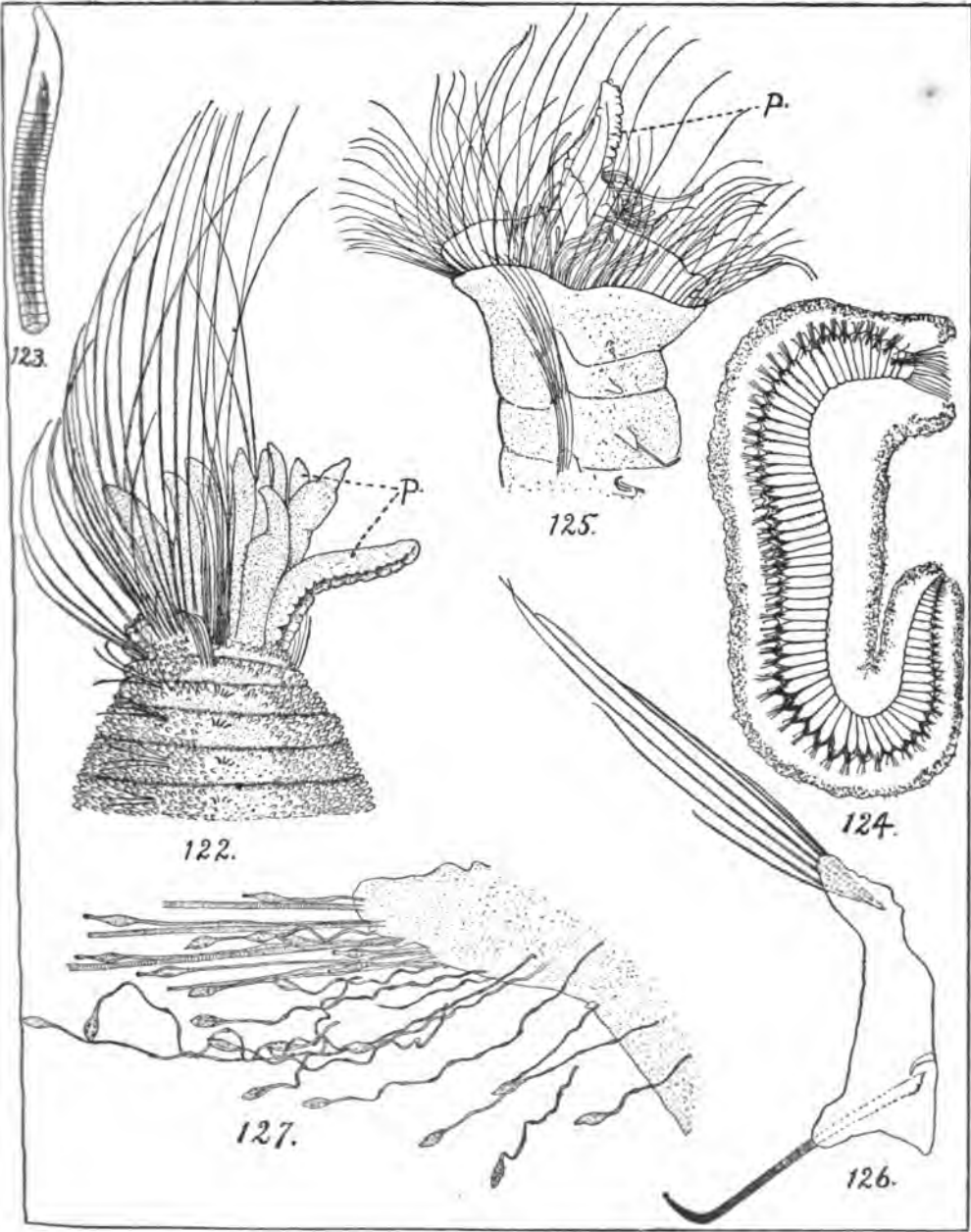


PLATE 13.

Figs. 128-133. *Clymenella rubrocincla*.

- Fig. 128. Profile of anterior extremity, right side. The rows of uncini on second and third somites are represented by dots. *pp.* Palpode. $\times 6$.
Fig. 129. Cephalic plate, dorsal aspect, showing palpode (*pp.*) and nuchal organs (*n. o.*) in form of heavy dark lines. $\times 9$.
Fig. 130. Anal rosette and perianal cirri. The ventral nerve-cord is continued into the long ventral cirrus. $\times 6$.
Fig. 131. Uncinus from fifth somite, with five teeth. $\times 275$.
Fig. 132. Uncinus from twelfth somite (ventral portion of fascicle), with six teeth; those in more dorsal portion of fascicle are five-toothed. $\times 275$.
Fig. 133. Capillary, serrulate seta from fifteenth somite. $\times 321$.

Figs. 134-139. *Nicomache personata*.

- Fig. 134. Anterior portion, ventro-lateral aspect. $\times 9$.
Fig. 135. Posterior extremity, showing pygidium and circlet of cirri. $\times 9$.
Fig. 136. Stout ventral spine from third somite. $\times 150$.
Fig. 137. Uncinus from fifth somite. $\times 275$.
Fig. 138. Setae and filaments, posterior region. $\times 39$.
Fig. 139. Double-bordered, capillary seta from dorsal fascicle. $\times 187$.

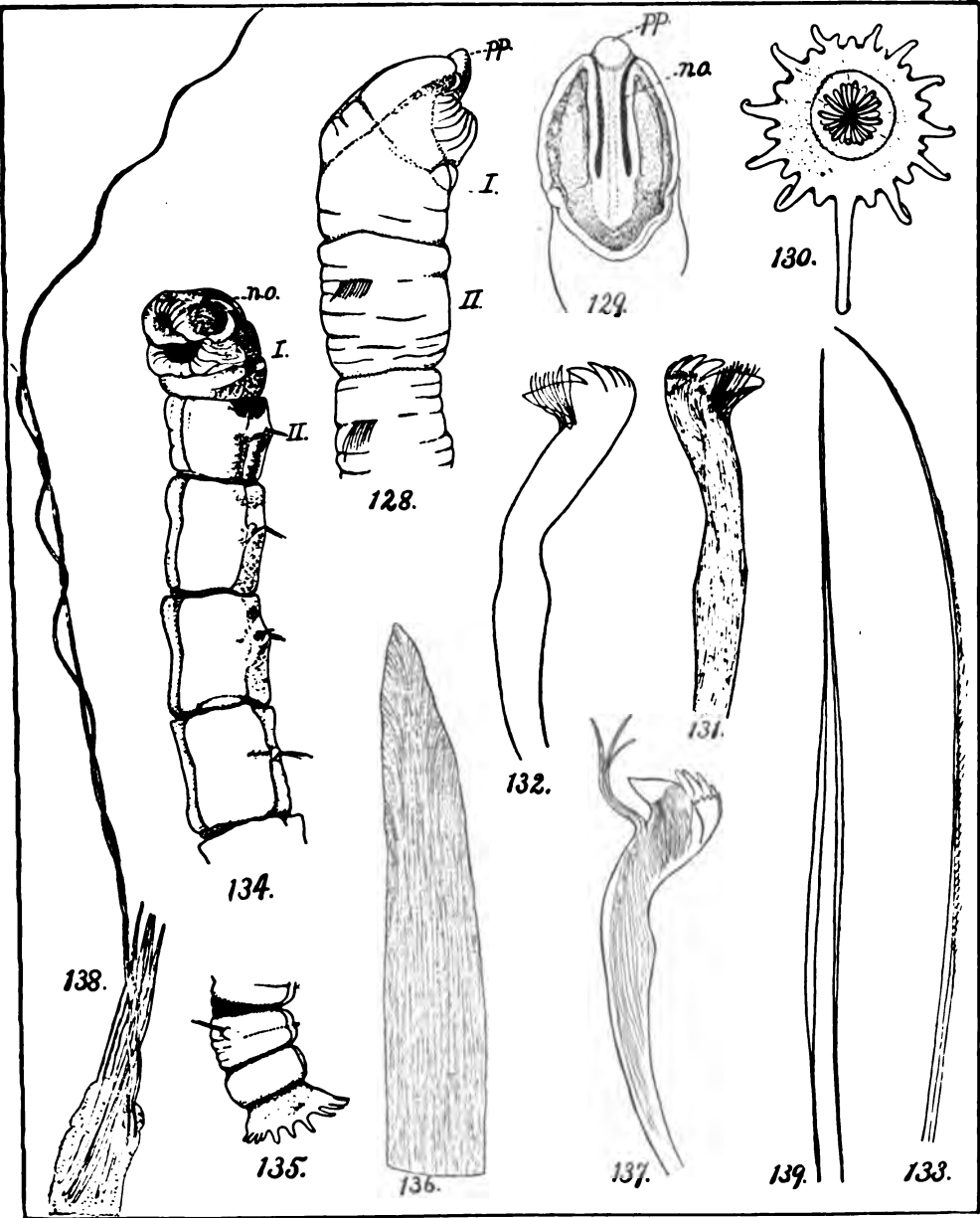


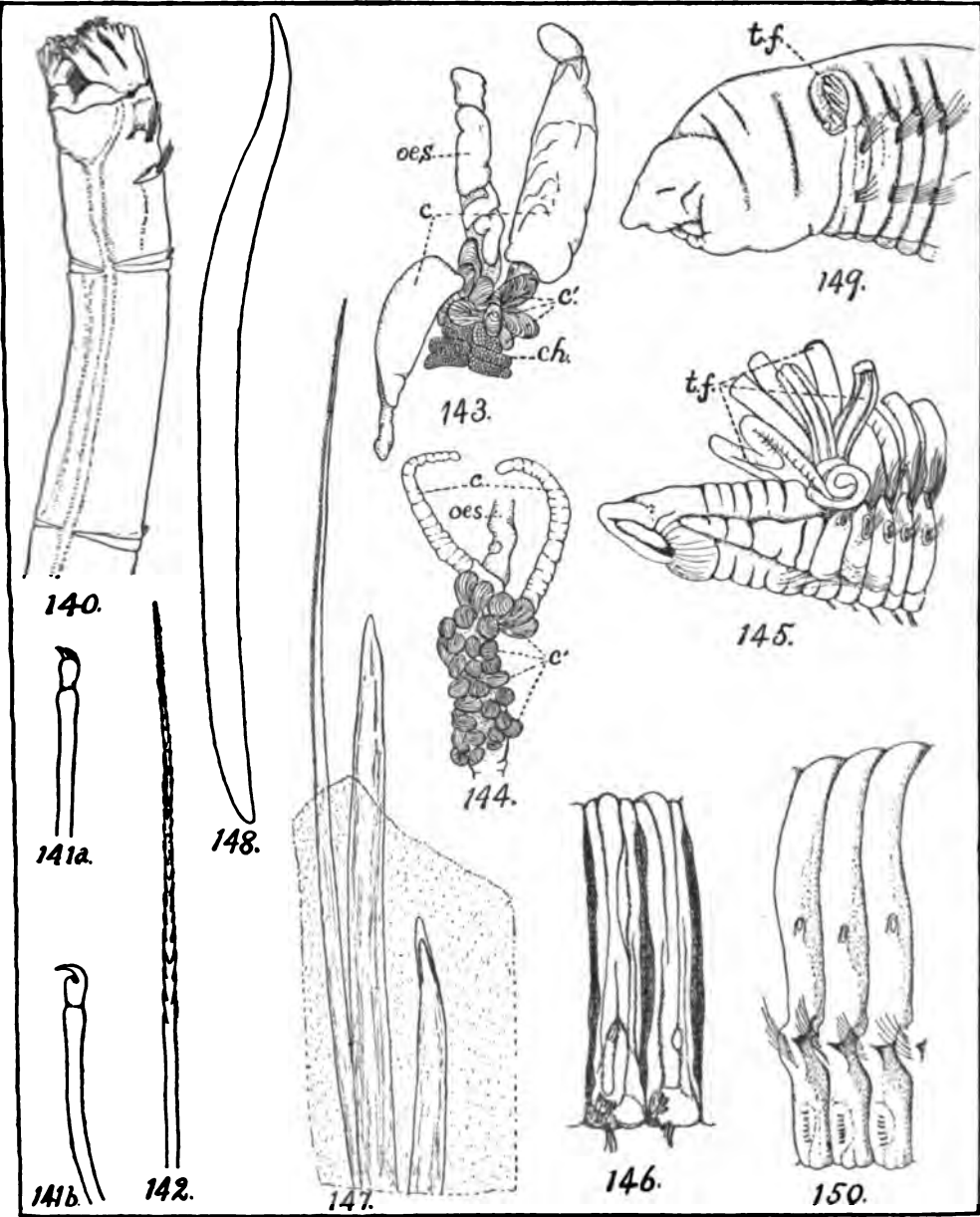
PLATE 14.

Figs. 140–142. *Ammochaeres occidentalis*.

- Fig. 140. Anterior portion, ventral aspect. The tori are represented, but the uncini are invisible at this magnification. $\times 13$.
- Figs. 141 a, b. Uncini, frontal aspect and profile. When *in situ*, only the portion distal to the constriction is exposed. $\times 600$.
- Fig. 142. Seta, showing double serration. $\times 450$.
- Fig. 143. Portion of digestive tract of *Arenicola claparedei*, showing lower section of oesophagus (*oes.*); oesophageal coeca of two kinds (*c*, *c'*), and the anterior extremity of the chlorogogenous tract (*ch.*). The most anterior pair of coeca (*c.*) are always much larger than the rest, thin-walled and highly vascular. The other coeca (*c'*.) are thick-walled and the surface is striated. They are not always paired, and the number is highly variable (ten in the present instance, which is about the minimum). Free-hand drawing. $\times 2$.
- Fig. 144. Oesophageal coeca of another specimen, showing the thin-walled, vascular pair (*c.*) in a much-contracted condition. The smaller coeca (*c'*.) number fifteen on each side (with one exception the highest number hitherto observed) and are quite uniform as to size. Several are attached at or near the median line. Free-hand drawing. $\times 2$.

Figs. 145–148. *Cirratulus cingulatus*.

- Fig. 145. Anterior portion, showing tentacular filament (*t. f.*) and three most anterior pairs of cirri, all cut short. $\times 9$.
- Fig. 146. Two somites from middle of body. The dorsal cirri are broken off, but the points of attachment are shown. $\times 13$.
- Fig. 147. Ventral setae, and two uncini *in situ*. $\times 187$.
- Fig. 148. Ventral hook, middle region. $\times 150$.
- Fig. 149. Anterior portion of *Cirratulus robustus*. The tentacular filament (*t. f.*) and dorsal cirri are broken off at point of attachment. $\times 9$.
- Fig. 150. Somites 36–38 (anterior third of body), left side of the same. Points of attachment of cirri are distinctly shown. $\times 13$.



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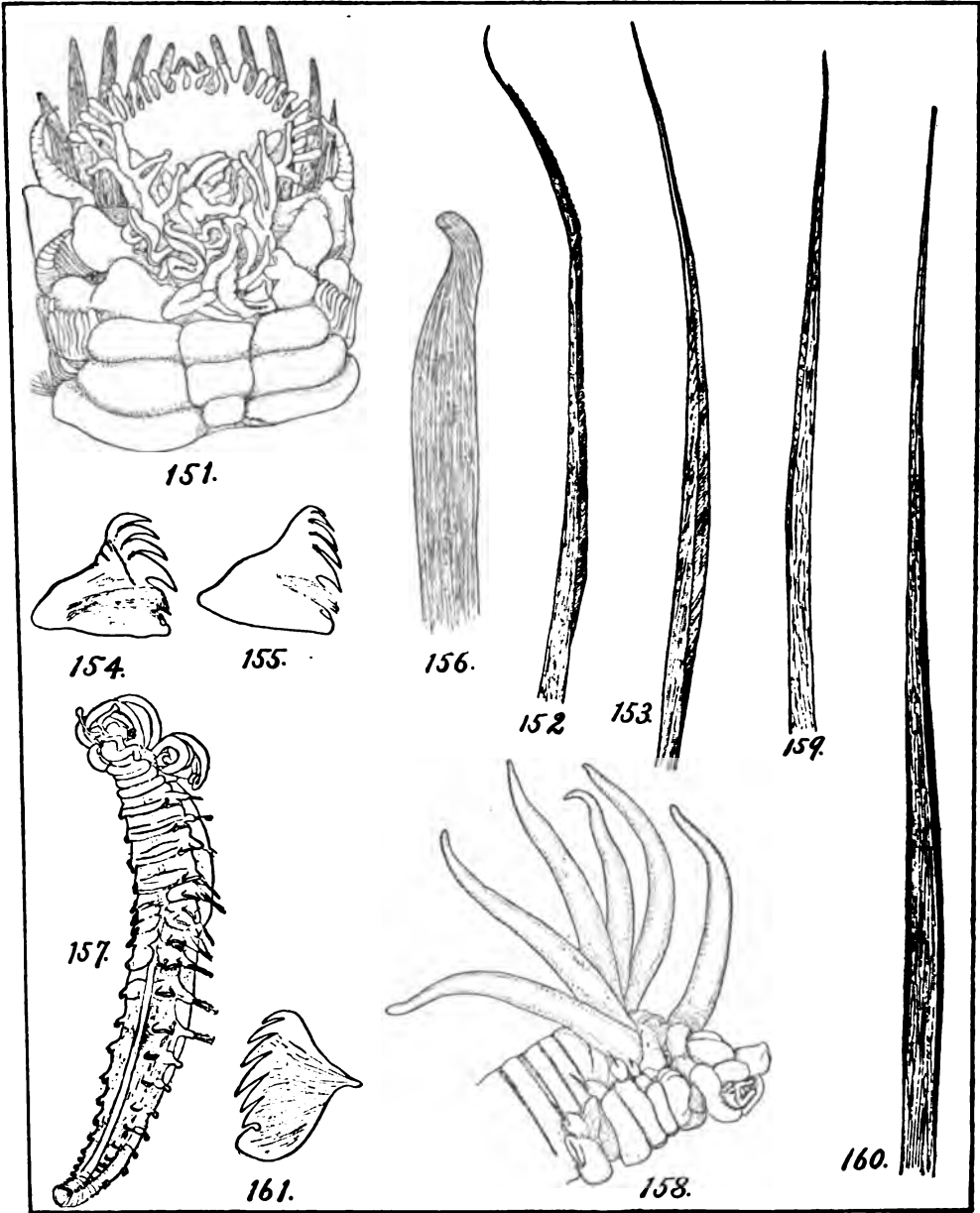
PLATE 15.

Figs. 151–156. *Pectinaria brevicoma*.

- Fig. 151. Anterior end, ventral aspect. $\times 9$.
Fig. 152. Seta from ninth somite, with striated border; slightly twisted. $\times 100$.
Fig. 153. Seta with striated border; not twisted. $\times 150$.
Fig. 154. Usual form of uncinus; from seventh somite. $\times 321$.
Fig. 155. Occasional form of uncinus; from twelfth somite. $\times 321$.
Fig. 156. Scapha-hook, showing laterally-bent tip. $\times 150$.

Figs. 157–161. *Sabellides unops*.

- Fig. 157. Entire animal, ventro-lateral aspect. Posterior extremity wanting, as are also most of the tentacles. Free-hand drawing. $\times 2.5$.
Fig. 158. Anterior extremity, right side, tentacles retracted. Two of the branchiae have been removed from the left side. $\times 6$.
Fig. 159. Single-bordered capillary thoracic seta. $\times 187$.
Fig. 160. Double-bordered capillary thoracic seta. $\times 321$.
Fig. 161. Uncinus, lateral aspect. $\times 321$.



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PLATE 16.

Fig. 162. Anterior extremity of *Sabellides anops*, dorsal aspect. Branchiae on right side have been cut off at the base. The somites 1-5 are numbered. $\times 9$.

Fig. 163. Prostomium and tentacles of the same, dorsal aspect. $\times 15$.

Figs. 164-168. *Amphitrite robusta*.

Fig. 164. Gill, mounted in glycerine. $\times 6$.

Fig. 165. Seta from thorax. $\times 187$.

Fig. 166. Uncinus from eighteenth somite, in profile. $\times 321$.

Fig. 167. Biserial arrangement of uncini, thoracic region. $\times 321$.

Fig. 168. Uncinus from near posterior end. $\times 321$.

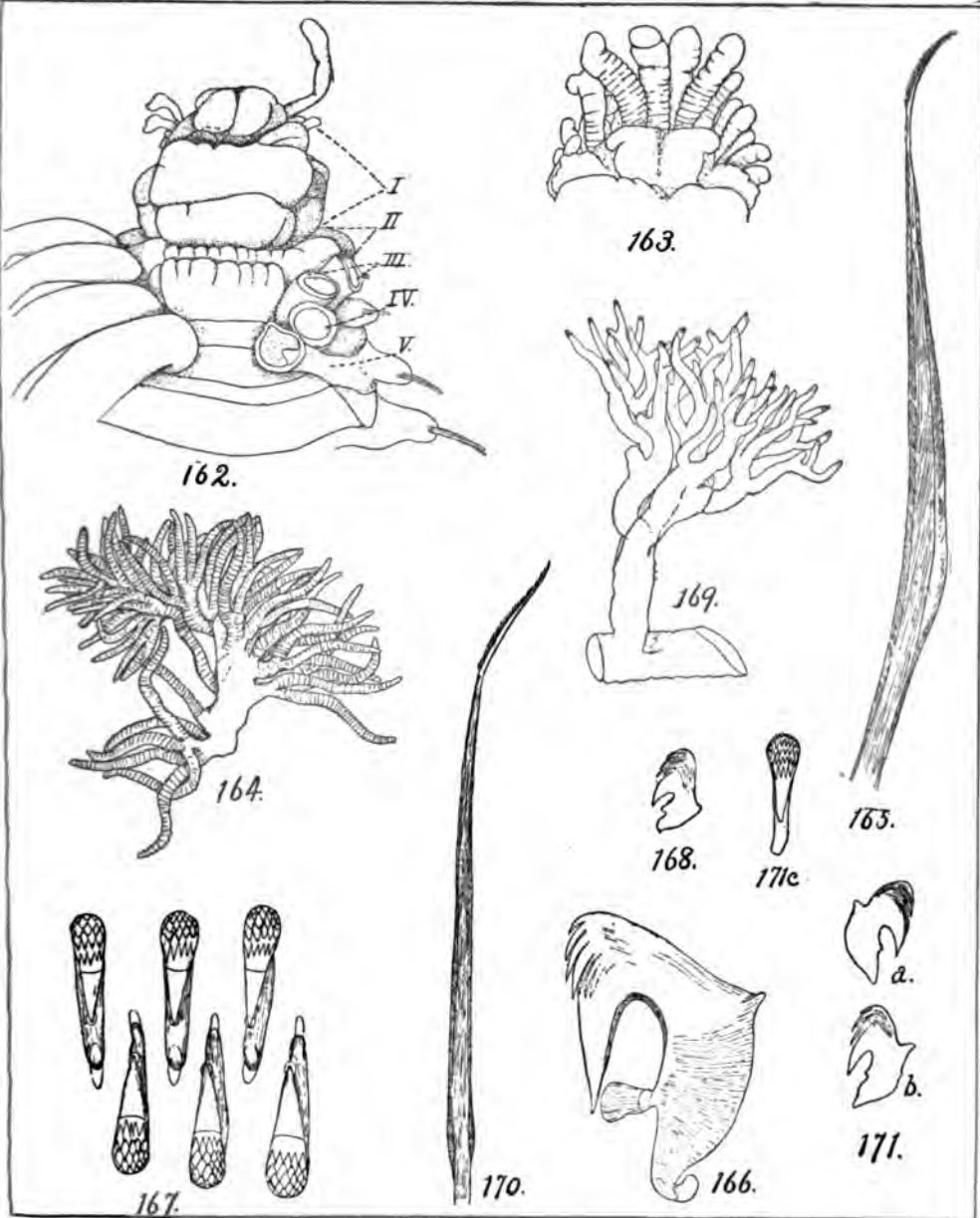
Figs. 169-171. *Amphitrite spiralis*.

Fig. 169. One of the main branches of a gill. $\times 15$.

Fig. 170. Seta from eighteenth (thoracic) somite. $\times 321$.

Fig. 171 *a, b*. Uncini from eighteenth somite, profile. $\times 321$.

Fig. 171 *c*. Uncinus, anterior aspect, showing five rows of teeth above rostrum. $\times 350$.



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PLATE 17.

Figs. 172-174. *Lanice heterobranchia*.

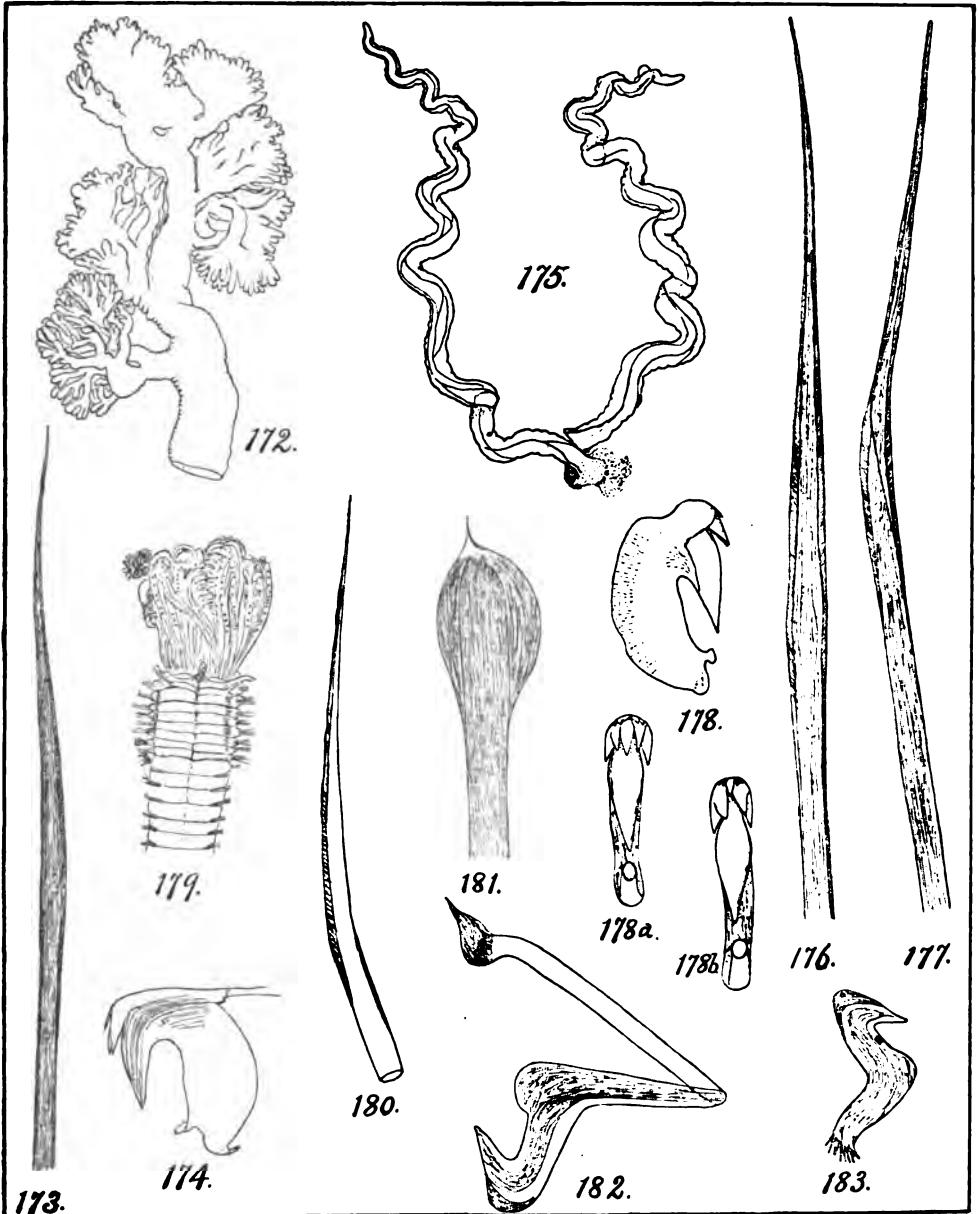
- Fig. 172. One of the first pair of gills; only one branch is given in detail. $\times 9$.
Fig. 173. Capillary, double-bordered thoracic seta. $\times 187$.
Fig. 174. Uncinus from nineteenth (thoracic) somite. $\times 321$.

Figs. 175-178. *Thelepus crispus*.

- Fig. 175. Two gill-filaments, showing place of attachment to body. In glycerine. The blood-vessels show through the translucent walls. $\times 9$.
Figs. 176, 177. Two capillary double-bordered setae of differing form. $\times 150$.
Fig. 178. Uncinus from thirty-second (thoracic) somite, profile view. $\times 321$.
Fig. 178 a, b. Two thoracic uncini of slightly different form. $\times 350$.

Figs. 179-183. *Bispira polymorpha*.

- Fig. 179. Anterior portion, ventral aspect, including thorax and first six somites of abdomen. Free-hand drawing. $\times 2$ (circa).
Fig. 180. Winged seta from dorsal portion of sixth fascicle. $\times 150$.
Fig. 181. Spatulo-mucronate seta-tip from ventral portion of sixth fascicle. $\times 275$.
Fig. 182. Avicular and mucronate uncini from sixth torus, in their normal relation to each other. $\times 150$.
Fig. 183. Avicular uncinus from abdominal region (twentieth torus). $\times 150$.



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PLATE 18.

Fig. 184. Portion of gill of *Bispira polymorpha*, near base, showing gill-filaments and two eyes. $\times 39$.

Fig. 185. Double-bordered, capillary seta from abdominal region. $\times 150$.

Figs. 186–192. *Megachone aurantiaca*.

Fig. 186. Thorax, and first somite of abdomen, right side. Collar is clearly indicated. $\times 6$.

Fig. 187. Anterior extremity in end-view, showing regenerating (?) branchiae, appressed upon the disc; their tips point ventrad. $\times 9$.

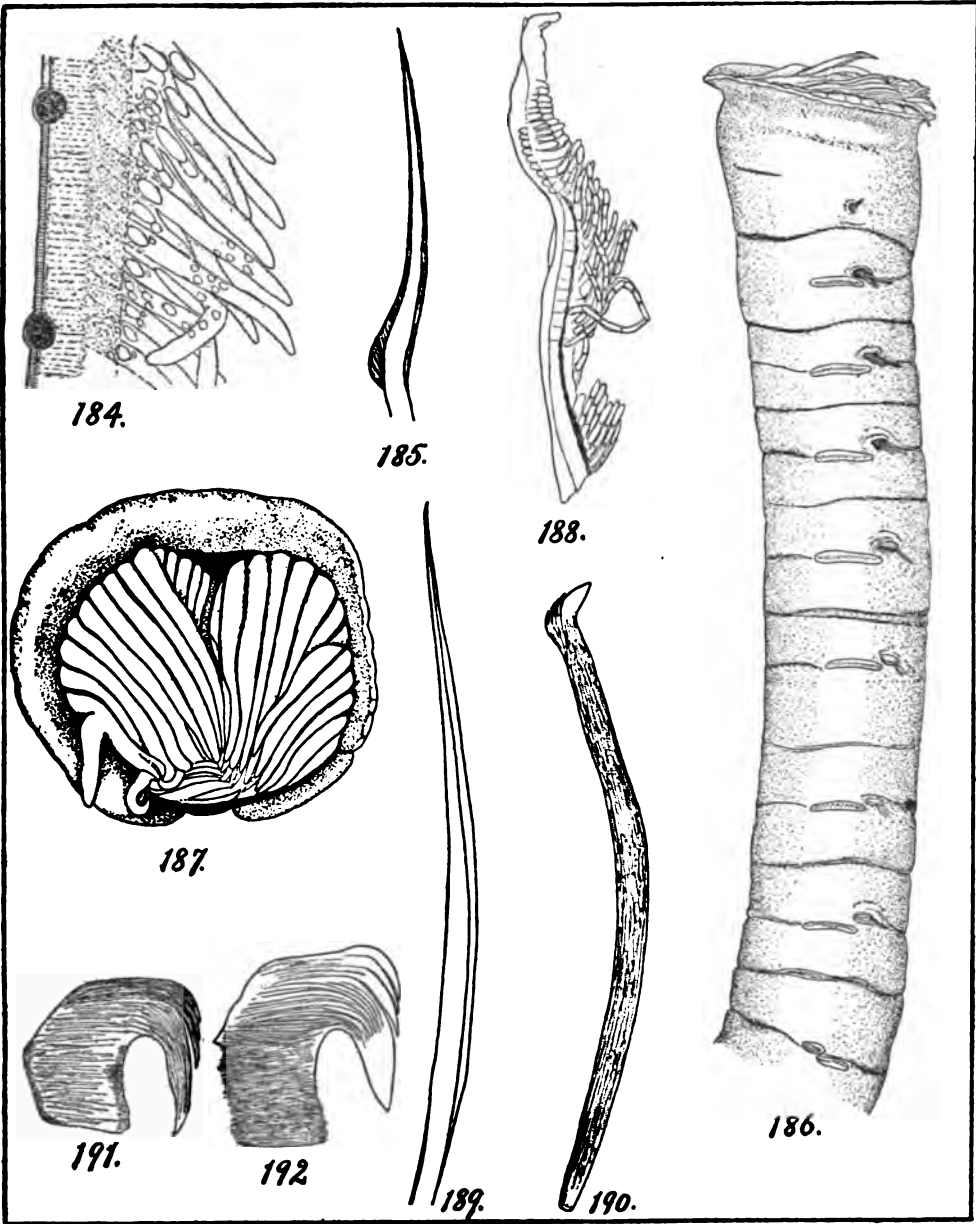
Fig. 188. Gill showing filaments, the blood-vessels of which contain oval blood-clots. $\times 20$.

Fig. 189. Bordered seta, from thorax. $\times 187$.

Fig. 190. Uncinus from sixth torus. $\times 150$.

Fig. 191. Uncinus from nineteenth torus. $\times 275$.

Fig. 192. Uncinus near posterior extremity. $\times 275$.



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PLATE 19.

Figs. 193-198. *Myxicola pacifica*.

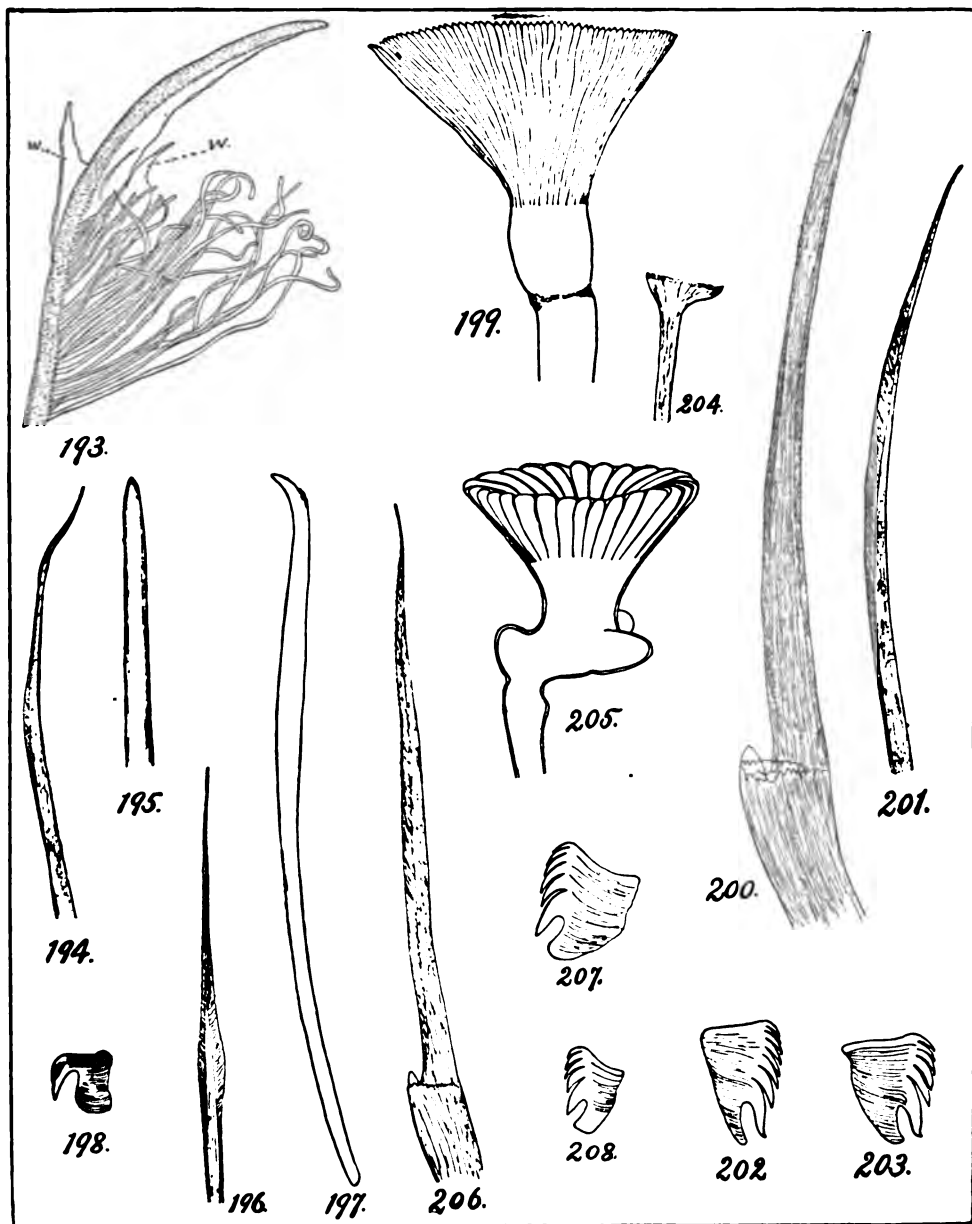
- Fig. 193. Tip of branchia. The web connecting the branchiae is shown as a border on the right side, and as ruptured tips at *w. w.* $\times 12.5$.
Fig. 194. Double-bordered, thoracic seta. $\times 450$.
Fig. 195. Stout, straight seta from thorax. $\times 450$.
Fig. 196. Abdominal seta. $\times 450$.
Fig. 197. Thoracic uncinus. $\times 321$.
Fig. 198. Abdominal uncinus. $\times 321$.

Figs. 199-203. *Serpula columbiana*.

- Fig. 199. Profile view of operculum. $\times 6$.
Fig. 200. "Bayonet" seta from first fascicle. $\times 187$.
Fig. 201. Thoracic seta with striated border. $\times 187$.
Fig. 202. Thoracic uncinus (many are 6- or 7-toothed). $\times 275$.
Fig. 203. Abdominal uncinus. $\times 275$.

Figs. 204-208. *Serpula zygonophora*.

- Fig. 204. Chisel-shaped, abdominal seta. $\times 321$.
Fig. 205. Profile view of operculum. $\times 9$.
Fig. 206. "Bayonet" seta from first fascicle. $\times 187$.
Fig. 207. Thoracic uncinus (6-toothed). $\times 321$.
Fig. 208. Abdominal uncinus (usually 6-toothed). $\times 321$.



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